A Study of Design and
Operations of Actual and
Potentially Suitable CLM Burners

Final Report

By

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Consultant

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MICROMEDIA

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CLM BURNER & OPERATING EXPERIENCE STUDY
TRIP NO. 1 - LIST OF CONTACTS - July 5 - July 23, 1982

PAGE 1

ITEM NO.	COMPANY	ADDRESS	TELEPHONE NO.	PERSON CONTACTED	TITLE	DATE SEEN	REMARKS
1	Babcock & Wilcox Co.	205 Van Buren Avenue Barberton, Ohio 44203	216-753-4511	Jos. Barsin	Mgr. Combustion Systems Fossil Power Generating Division	6-7-82	Developing "T" atomizer expected life 600 hrs.
2	Hauck Manufacturing Company	100 North Harris St. Lebanon, Pa., P.O. 390 17042	717-272-3051	J.A.Marino	Vice-President	8-7-82	Cuptip low velocity atomizer external
3	Process Combustion Corporation	1675 Washington Rd. Pittsburgh, Pa. 15228	412-561-6200	P. Hutcher	Vice-President	9-7-82	Vortex Cup low velocity external
4	Pittsburgh Engineering Technology Ctr.	P. O. Box 10940 Pittsburgh, Pa. 15236	412-675-5715 412-675-5717	D. Bienstock R.C.Kurtzrock	Mgr. Comb.Projects Mgr. CLM Projects	12-7-82 12-7-82	COM on way out -CWM on way in. 1000 Hr. Life Tungsten Carbide Tip.
5	CONCO-owned 1/3 Dravo, 1/3 Massey Coal, 1/3 FPC	One Oliver Plaza Pittsburgh, Pa. 15222	412-566-5924 412-566-5140	J.C. Wilda J.S. Pekor	Mgr. Com.Development Application Eng.	13-7-82 13-7-82	Expect to be in COM commercial production in 1983.
6	Fuel Development Group Inc.	P.O. Box 98220 Pittsburgh, Pa. 15227	412-653-3960	Mr.Pomerance G. Leighton			Not seen. No answer to my phone call.
7	National Air Oil Burner Co.	1284 East Secgley Ave. Philadelphia, Pa.	215-743-5300	G.Bitterlick	V.P. & Chief Eng.	15-7-82	Obtained data on refinery refuse emulsion burner.
8	Faber Burner Division of Keeler-Dorr-Oliver Co. Agent S.I.E. Co.	236 West Street Williamsport, Pa. 17701 280 Halpern, Dorval, P.Q.	717-326-3361 514-631-6718	D.Cron W. Horton G. Babin	Eng. - Faber Div. Gen. Mgr.-Faber Mgr.	11-8-82	Faber have made successful test run on 50% COM (few hrs.). Will be making short run test on CWM in Sept.
9	Atlantic Richfield Oil Co.	Newton, Pa. (near Philadelphia) Harvey, Ill. Los Angeles, Ca.	215-359-2106 312-333-1463 213-466-0941	Dr. P. Ryan F. Chloupek J. Siemsen	Chief Chem. Div.	15-7-82	Dr. Ryan advised me to contact Chloupek & Siemsen for CLM info. Did not contact as locations off travel circuit.

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TRIP No. 1 - LIST OF CONTACTS - July 5 - July 23, 1982
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ITEM NO.	COMPANY	ADDRESS	TELEPHONE NO.	PERSON CONTACTED	TITLE	DATE SEEN	REMARKS
10	Niro Atomizer Inc.	9165 Ramsey Road Columbia, Maryland 21045	301-997-8700	S. Mortensen H. Mullendone	Chief R & D Engineer	18-7-82	Discussed Niro as burner & coal flash drying.
11	Atlantic Research Corp.	5390 Cherokee Ave. Alexandria, Va. 22314	703-642-4088	Dr. E.McHale	Tech. Div. ARC-Coal	19-7-82	Discussed principle ARCO CLM burner & ARCO work on CWM.
12	Pillard Inc.	3207 St. - Keger Bldg. Richmond, Va. Box 121 23288	804-288-1141	E.U.Heumann H. Drop	Chief Eng.		Not seen. (Had previous phone discussion Pillard).
13	Eastern Seabord Petroleum Co. ("Emulsofier")	7779 Bayberry Road Jacksonville, Fla. 32216	904-731-9426	D. Bender J. Orven	R & D Eng. Manager	20-7-82	Bender stated Mfg. water emulsified oil. See Georgia Pacific Report by R.Nesbitt.
14	COM Energy Inc. Subsidiary of Occidental Petroleum	5911 Buffalo Ave. Jacksonville, Fla.	904-355-3194	M. Sharkey	Plant Mgr.	21-7-82	In completion stage large commercial development COM.
15	Georgia Pacific Pulp & Paper Co.	Palatka, Fla.	904-325-2001	R. Nesbitt	Mgr. Power & Recovery	21-7-82	Telephoned - just leaving town - Using water-oil "Emulsofier" - see his paper.
16	Florida Power & Light Co. (Sanford Plant)	Juno Beach Office P.O. Box 14000 Juno Beach, Fla. 33408	305-863-3604	Dr. K.R.Olen	Head - R & D	22-7-82	1000 Hrs. life experienced with latest modified ICL atomizer at FPLC Sanford Station (Oil designed boiler).
17	Florida Power Corp.- BartowPlant Weeden Island St. Petersburg	F.P.C.-Paul Bartow Plant P.O. Box 14042 St.Petersburg, Fla. 33733	Admin.Office 813-866-5151	F. Martin J. Waldo	Plant Mgr. Plant Eng.	23-7-82	COM experience only 2 mos.- "Peabody" Bullet Burner. N.B.Bartow Tel. No. per se Not listed.
				M.E. Higgins	Tech. Services Supt.	29-9-83	Discussed Dudley-Higgins modification

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CLM BURNER & OPERATING EXPERIENCE STUDY
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ITEM NO.	COMPANY	ADDRESS	TELEPHONE NO.	PERSON CONTACTED	TITLE	DATE SEEN	REMARKS
1	Kaskin Co. c/o S.D.Combustion Ltd.	6650 P.E.Lamarche Montreal, H1P 1J8	326-0440	Roger St-Denis	President	5-11-82	
2	Combustion Equip. Assoc.-Div. of Henry Simon (England)	585 Curé Boivin Boisbriand, Québec J7G 2A8	435-1961	François Grimard	President	15-10-82	
3	Ontario Research Foundation	Sheridan Park Reasearch Community Mississauga, Ontario L5H 1B3	416-822-4111	Lou Bruno	Mgr. Eng.& Combustion Systems, Dept. of Eng. & Metallurgy	13-10-82	9:30 a.m.
4	Conamara Ltd. (Vortometric)	2180 Spears Road Oakville, Ont. L6L 2X8	416-825-1400	L.E.Anderson F. M.Williams	Dir. of Research & Dev.	13-10-82	2:30 p.m.
5	North American Mfg. Co.	4455 East 71st St. Cleveland, Ohio	216-271-6000	Don Moreland John Ransdell Jas. Watson	Sales Manager Mgr. of Eng. R.&D. Engr.	14-10-82	
6	Fluid Kinetics Co.	4859 Factory Drive Fairfield, Ohio (Off Hicks Blvd.)	513-829-7200	Paul Koppehele Gerry Malinak	President	15-10-82	
7	Arco Petroleum Products Co.	400 East Sibley Blvd. Harvey, Ill. 60421	312-333-3000	F. Chloupek	Mgr. Venture Planning & Business Development	19-10-82	Ref. Dr. Ryan of Arco. Newton, Pa.
8	Forney Engineering Co.	3405 Wiley Post Road P. O. Box 189 Addison, Texas 75001	214-233-1871 214-458-6596 214-233-1871	Dr. John Eberlie Mr.J.O. Toutz Norman Buckland Robt.H.Hickman	V.P.- Engr. Super.Burner Engr. Mgr. Comb. Dept.	18-10-82	

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LIST OF CONTACTS - TRIP NO. 2

ITEM NO.	COMPANY	ADDRESS	TELEPHONE NO.	PERSON CONTACTED	TITLE	DATE SEEN	REMARKS
9	National Research Council (Flo-Sonics)	Montreal Road Ottawa, Ont. K1A 039	1-613-993-0198 1-613-993-2455	Dr. Ed. Capes Dr. Wm.Thayer Mr. R. Jonson	Head Chem.Eng. Sect. Chem. Eng. Chem. Eng.	07-09-82 07-09-82 07-09-82	
10.	C.E. Superheater Canada	99 Bank St. Ottawa, Ontario K1P 6C5	1-613-560-4545	Dave Winship Fred Sailer Jas. Kearns	V.-P. Eng. Dir. of Eng. Coordinator	08-09-82 08-09-82 08-09-82	

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LIST OF CONTACTS - TRIP NUMBER 3 (August 28 - August 29, 1983)

ITEM NO.	COMPANY	ADDRESS	TELEPHONE NO.	PERSON CONTACTED	TITLE	DATE SEEN	REMARKS
1	Combustion Engineering Inc.	1000 Prospect Hill Road Windsor, Conn., 06095	(203)698-1911 Ext. 2448	D.A. Smith 9005-0301	Supervisor Combustion Component Research	28-6-83	Phone discussions and confirming letters leading to C.E. Canada meeting in Ottawa.
2	Combustion Engineering Canada	99 Bank Street. Ottawa, Ont. K1P 6C5	(613)560-4545	David Winship James Kearns	President, Performance Design Engineering	3-8-83	Full hard fact discussion on C.E. Canada's Chatham atomizer.
3	W.N. Best Combustion Equipment Co. Division of Preferred Utilities Co.	11 South St. Danbury, Conn. 06810	(203)743-6741	John Akin Richard Stone D.R. Perkins	Gen. Mgr. President V.P. Sales	28-8-83	Full data on "lip" burner. Discussed potential CLM for "lip" rotary atomizers.
4	Johnston-Macco Division of Schlumberger Technology Corp.	P.O. Box 36369 Houston, Texas 77036	(713)491-1313	M.G. Wilcox	Sr. Staff Engineer for USA & Canada	15-7-83	See letter Aug. 9, 83 re Flopetrol "Mud" burner in reports.
4.1	Flopetrol Limited	1400 Broodfield Ave. Houston, Texas 77084	(713)492-6000	Gilbert Prongué G.L. Hillman	Manager Asst. to Mr. Prongué for areas outside USA & Canada	15-7-83 4-8-83	See letters July 29 & Aug. 4, 1983 in reports.
5	Peabody Engineering Corp.	835 Hope St. Stamford Conn., 06907	(203)327-7009	Ray Frauenhofer	Supervisor, Fuel Burner Equipment	18-7-83	Tel. discussion revealed no R & D activity on CLM.

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CLM BURNER & OPERATING EXPERIENCE STUDY

LIST OF CONTACTS - TRIP NUMBER 3

ITEM NO.	COMPANY	ADDRESS	TELEPHONE NO.	PERSON CONTACTED	TITLE	DATE SEEN	REMARKS
6	Sonic Energy Combustion Systems Inc. (Subsidiary of Sonic Engineering Energy Co.)	102 East 12th Street Wilmington, Delaware 19802	(302)652-7164	Robert Schurigh	Gen. Manager	14-7-83	Tel. discussion revealed no R & D on Sonicore Burner for CLM since Halifax Shipyards problem job.
7	John Zink Company (Can. subsidiary is John Zink Canada in Mississauga, Ont.)	4401 S. Peoria Ave. Tulsa, Okla. 74105	(918)747-1371	Dr. Richard Waibel	Tech. Director Burner Division	12-7-83	See letter Aug. 9, 1983 in Report B.

LIST OF REPORTS

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2	9	Hauck Manufacturing Company	Hauck
3	14	Process Combustion Corporation	Urquhart
4	16	Comco	COM Mfr.
5	18	Pittsburgh Energy Technology	Centre
6	22	Fuel Development Group	Applicators
7	23	National Airoil Burner Co.	N.A.O.
8	26	E. Keeler Co. - Faber Burner Division	Faber
9	28	Atlantic Richfield Oil Co.	R & D on CLM
10	29	Niro Atomizer Inc.	Niro Burner; Niro Coal Flash dryer
11	31	Atlantic Research Corp.	R & D on CWM
12	34	Pillard Inc.	Pillard
13	35	Eastern Seabord Petroleum Co.	Mfr. of water-oil emulsion.
14	37	COM Energy Inc.	COM mfr.
15	39	Georgie Pacific Pulp & Paper Co.	User of water-oil emulsion.
16	40	Florida Power & Light Co.-Sanford Plant	User of ICL COM Burner.
17	53	Florida Power Corp. - Bartow Plant	User of Peabody "Bullet" Atomizer
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19	62	Forney Engineering Co.	Forney CWM Atomizer
20	66	North American Mfg. Co.	N.A. Atomizers
21	69	National Research Council (Ottawa)	Flo-Sonics Atomizer
22	72	Combustion Equipment-Superheater Canada Ltd.	C.E. CLM Burner
23	74	Combustion Equipment Associates	Comb. Technology Intl. with B.P. - England - re COM Burner Development
24	76	J.F. Raskin Inc.	Raskin-Coen Burner

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26	79	Conamara Ltd.	AECO Burner (formerly Vortometric)
27	82	Fluid Kinetics	Origin of Canadian Flo-Sonics Burner
28	84	W.N. Best - Division of Preferred Utilities	W.N. Best "LIP" Atomizer
29	85	Combustion Engineering Co.	Y-Jet Design for Chatham Demonstration CWM
30	93	Flopetrol Co., Division of Schlumberger Co.	Flopetrol "MUD" Burner
31	100	Sonic Engineering Co.	Sonicore Burner
A	101	Peabody Engineering Co.	Peabody "BULLET" Burner
A[1]		Peabody Engineering Co.	1) Peabody "BULLET" atomizer as modified by Dudley-Higgins of Florida Power Corp.
B	102	John Zink Co.	Zink Burner under R & D for CLM Fuels

1) See Addendum No. 1 to Report on Florida Power Corp. - Section 17.

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B	Sections 3, 11, 20(c), 16, 28, 2, 19, 21, 25-26	1-3	124
B1	Sections 1, 7, 20(a), 20(b), 8, 17, 29	1.1-3.1	127
B2	Points Rating Basis	1-2	130
B2-1	Refer E.M.R. - Dr. H. Whaley - CCRL	1	132
C	Coal-Water Atomizer Life vs Change Frequency	1	133
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3	"Combustion of Coal/Water Slurry"	E. T. McHale et al from "Combustion & Flame" 42 - (1982)	251
4	"Development and Evaluation of Highly Loaded Coal Slurries"	E. T. McHale Atlantic Research Corp for P.E.T.C.	266
5	"Advances in Combustion Technology"	H. J. Taback & H. R. Taplin for Association of Energy Engineering Congress - Atlanta, Georgia	275
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6	North American	Tip Emulsion Atomizers, Model 56.43, Pages 1-4.	306
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12	Flopetrol	Designed for use in oil fields to burn waste hydrocarbons.	322

INTRODUCTION

In the Spring of 1982, Canada had a requirement for a catalogue of oil and gas atomizers whose basic design (and operating experience) would provide a maximum probability of success in the burning of coal-liquid-mix mixture (CLM) fuels such as coal-oil mixtures (COM) and particularly coal-water-mixtures (CWM).

The criteria for assessing actual or potential merit were:

1) Atomizer Life - operating hours before need of replacement

2) Atomization Capability -
   a) for one or more types of mixtures rheologies
   b) atomizing fluid consumption kg/kg fuel.

3) Generic Types -
   a) external atomizing
   b) internal atomizing
      a1) full emulsion
      b1) tip emulsion
   c) hybrid, i.e. an external type with some internal mix characteristics.

4) Efficiency of atomization -
   a) atomized droplet size distribution
   b) spray angle control of atomized fuel
   c)[1] contribution to low excess air operation
   d)[1] contribution to high carbon burn-out.

5) Ability to manufacture atomizers in alloy steel or ceramic or wear resistant materials in whole or in part.

6) R & D capability of organization.

7) Operating experience with CLM.

1) The word "contribution" is used because the total burner design, including as a principal factor, the vane register system plays a very important part in flame control and combustion efficiency.

DISCUSSION

1. In preparation for this work I developed a detailed technical questionnaire form and from the data obtained from the burner manufacturers I made the tabulations shown in Tables 1, 1A, 1B, 2, 2A, 2B containing a total of 43 major headings.

2. A total of 30 contacts were made of which 7 were telephone discussions and 23 were direct interviews with qualified management personnel, as listed in the List of Contacts and in the Reports Section of this work.

2.1 Of the interviewed group, 3 were research centres:- the Pittsburgh Energy Technology Centre, the Ontario Research Foundation, and the National Research Council (Canada).

2.2 From the ORF I obtained data on the Gulf-Vortometric atomizer which was supplemented by Conomara Ltd. and from NRC I received data on the Flo-Sonics atomizer, supplemented by Fluid Kinetics Ltd.

2.3 Also, in the group interviewed there were 5 CLM fuel manufacturers.

2.4 There were then 15 burner manufacturers interviewed, (including NRC as developer of the Flo-Sonics atomizer), with North American providing data on 3 types, thereby making a total of 17 atomizers in which technical data was obtained.

3. 17 atomizers were categorized under 43 headings making a total of 731 units of information.

3.1 Therefore to provide a means of assessing a merit value for each atomizer, Table B (continued on B.1) was devised with the more important atomizer data as column headings.

3.2 Then Table B.2 was devised to establish a means of identifying value for such data as could be given a value number. Where actual "hard facts" were obtained from the manufacturers, the corresponding value number is real. In other cases value numbers had to be assessed by the author's judgement based on the atomizer design.

... /2

4. It will be seen from Tables B and B.1 that the atomizers were categorized in groups: A - External; B - Hybrid, C - Internal-tip emulsion and full emulsion.

5. Of the Full External Atomizers types (as categorized by the author) only ICL had extended field experience at the Sandford Plant of the Florida Power and Light Co.

5.1 The known atomizer life was 1000 hours on 50/50 COM (with "special" alloy material) with an anticipated development to 2000 hours.

5.2 The ARCO burner designed by the Atlantic Research Corp. had small scale, short time test in their test furnace, at a one million BTU/hr rate on 60/40 CWM (commercial testing in a boiler was under consideration). The low erosion index of 3.85 (see Table page 3) should presage a good operating life.

6. In the Hybrid Class, Hauck had a short test in a commercial boiler, which was plagued by problems of COM fuel supply pressure and low temperature. With pressure and temperature normalized - good combustion was achieved.

6.1 The test results by ORF on the Vortometric and by NRC on the Flo-Sonics, show good promise on lifetime and generally on the full category of atomizer values. But a full commercial demonstration is required and, in my opinion, quite desireable.

6.2 The Forney burner now being tested at Chatham, is here characterized as a hybrid deisgn atomizer. The total results that will be achieved should prove very enlightening.

7. In the Internal Atomizing Class of atomizers, the "special" Y-Jet type of Combustion Engineering Canada is currently undergoing test at Chatham.

7.1 The design and operating characteristics of the C.E. Canada and B & W atomizers are, in many ways, similar with little difference in their value assessment.

... /3

7.2 As shown in Tables 1 & 2, B & W have had good experience with their "T-Jet" atomizer and their data provided a low erosion index number, with a 300 hour life demonstrated with tool steel metallurgy. The B & W nozzle has recently been field tested as part of an ERPI program in a 30 day test burn at the Dupont plant in Memphis. Their estimate of improvement to 600 hours is perhaps conservative.

8. It should be considered that the data presented in the Reports and in the Tables, date back to the July through October period of 1982.

8.1 Since those dates doubtless much new operating experience has been obtained from commercial testing over adequate time of run.

8.2 It is possible that since last year that numbers of manufacturers who had no or insufficient operating experience may by now have arranged for commercial operation.

8.3 Hopefully this will have included the Vortometric and Flo-Sonic burners and some of the promising USA designs.

9. There is a particular need, in my opinion, to have experience of, or with, a sufficient number of atomizers to meet the combustion needs of oil-fired design boilers, such as the "D" furnace watertube package type, in the capacity range upwards of 50,000 or 100,000 pph. In this category of boilers an important percentage of fuel oil is comsumed.

10. Table C was prepared to show the relationship between atomizer life in hours and the frequency of atomizer change for a 5000 hour operating year. This frequency number could have significance in the case of utility boilers having, say, 20 or more burners. This emphasizes the need of developing long life atomizers.

11. It was very interesting to read of the development of the Dudley-Higgins modification of the Peabody "Bullet" atomizer for both atomizing efficiency and life, - in the paper by W.E. Dudley, M.E. Higgins and D.H. Meyer, all of the Florida Power Corp. published in the Fifth International Symposium on Coal-Slurry Combustion, Tampa, April 1982.

... /4

I obtained the strong impression that there were no guiding scientific principles on which their R & D could be based and that their development depended on good judgement and trial and error techniques.

12. In reading the data on CLM production by companies like Comco and ARCO (for example), I found a variation in the engineering data they provided.

12.1 In the case of Comco, in a recent publication I found their Figure 10 on "Petcom" viscosities gave a linear relationship between viscosity in cP and % weight of "coal" in fuel oils of "high, low and intermidiate" viscosity, but no data on viscosity/shear rate relationship, from the rheograms of the slurry(s) in question. The viscosity range shown in Fig. 10 was 5,000 to 12,000 cP (approx. 23,000 to 55,500 SSU in terms of straight oil firing practice).

12.2 ARCO data in their Fig. B.1 (See Appendix II in this work) does give viscosity in cP versus shear rates up to 45 $sec.^{-1}$, for various soft coals and % coal concentrations. This figure shows the start of the ordinate asymptotic rise at a shear rate of 10 $sec.^{-1}$. This value is approximately the same as that shown in the paper by Dr. Daniel Bienstock and Edward M. Jamgochian (See foot note in the Report on "Pittsburgh Energy Technology Centre" in Section 5 of "Reports" in this work.) The viscosity in ARCO's Fig. B.1 is from 600 cP to 80,000 cP (at asymptote high) corresponding to shear rates of 45 $sec.^{-1}$ down to 1 sec. $^{-1}$ for various coals and % coal concentration in the CWM.

13. In the work by the Saskatchewan Research Council "Determination of Rheological Properties of Coal-Oil Slurries", (SRC Publication No. E-725-1-C-81) I found graphic material on which I comment as follows.

13.1 From Brookfield Viscometer graphs give shear stress (dynes/sq. cm.) angular versus velocity (1/sec).
To use this graph for pressure drop calculations, the geometry of the Brookfield Viscometer must be known to effect a calculation of a multiplying factor converting the ordinates (dynes/sq. cm.) to centipoise, corresponding to the shear rates derived from Brookfield geometry and rotational speed.

... /5

The centipoise value can then be used in the Poiseuille Equation to obtain pressure drop in psi/100 ft.

13.2 From a Vertical Tube Viscometer, graph data give:

Ordinates	DΔP/4L (dynes/sq. cm.)
Abscissa	8 V/D (1/sec)

From these graphs, there is a need only of converting the dyne/sq. cm. values to psi/100 ft. relative to D P/4L values to obtain pressure drop in psi/100 ft.

14. In Section 29, Report on C.E. Canada, item 13 shows shear rates due to velocity thru the atomizer exit ports of:

14.1 Emulsion - 190,053 ft./sec^{-1}
CWM only - 3395 ft./sec^{-1}

15. The question posed by such numbers is:
a) What is the "Viscosity" in the ports?
b) What momentum of atomizing fluids is required for adequate atomization, and how is this related to the "Viscosity"?

16. Scientific data on the question of viscosity "numbers" and corresponding atomizing fluid pressure and mass, has not come to my attention during the period of my work but I understand that research work on viscosity is being done by Dr. Funk at Alfred University and Dr. John P. Dooher at Adelphi University.

17. As a final comment.
Utility boilers resort to de-rating as required by the CWM abrasive qualities, ash content, and fusion temperatures.

17.1 I believe that knowledge of these factors are equally essential for successfull operation in commercial and industrial boilers.

18.2 Further, if these commercial and industrial boilers cannot be de-rated, then a knowledge of sources of highly beneficiated, low ash, low FPA, CWM from various parent coals, together with rheograms of these "other" CLMs is essential to the development of a CLM market in the commercial and industrial sectors. From the Florida Power Corp. data and experience, in their Paul Bartow plant, it may be found that only a suitable COM can be used in such boilers.

Babcock & Wilcox Co.
Barberton, Ohio

Date: 6-7-82

Meeting with Mr. Jos. A. Barsin
Manager, Combustion Systems
Fossil Power Division

1. Experience with original "Y" jet, even modified for COM-CWM, did not indicate sufficient life.

2. Testing was done on a "T" model atomizer (see sketch enclosed). Initial test was with tool steel material to determine wear zones - (these are marked in the enclosed sketch) after 300 hours of operation.

2.1 With alloy inserts and/or cladding, life is expected to increase, (conservative estimate) to 600 hours.

3. Test was made with CWM from a recirculating loop and the viscosity increased to 20,000 c.Poise. Increase in loop pressure was ten fold.

3.1 Viscosity increase effect was reduced by the addition of surfactants and water.

4. The Model "T" atomizer was designed for exit orifice(s) velocity of less than 5 ft/sec.

5. The coal used in the test mentioned in Item 2 was a Pittsburgh #8 with analysis as shown in Table 1 of Joe Barsin's paper entitled "Commercialization of Coal-Water Slurries" of February 16, 1982, copy attached.

6. N.B.: Joe Barsin advised that, in his paper the term KW was KW electric. (KWe). KW Thermal is identified as KW_t.

7. Carbon burn-out efficiency target was 5% carbon in ash - or a practical 90% total burn-out.

7.1 In addition to good efficiency, high burn-out is related to (a) boiler exit fouling factor (b) % boiler de-rating.

8. Joe Barsin stated that the limit to CWM temperature was the volatilization temperature of the surfactants. Surfactants were required (by all CWM mfrs.) for concentration >60%. Surfactants could be eliminated at concentrations <60%.

8.1 Max. CWM temp. tried by B & W was 235°F. The flash effect improved atomization.

8.2 Without surfactants in the CWM - it's temperature could be raised to 250°F with combustion air temp. up to 600°F.

9. B & W's first experience with CWM was at Jersey Central Power & Light, using Consolidation Coal in a "Cyclone" furnace.

10. Tests being scheduled by B & W are: -

a) In a 70.10^6 BTU/Hr. boiler in an industrial plant, scheduled for September.

b) In one burner of a Utility plant boiler, with burner rating of 180.10^6 BTU/Hr.

10.1 The fuels to be tested will be:-

CWM - 70% coal concentration
COM - 40% " "
COW - possibly "
Sludge from sewage waste.

10.2 The model number of the burner to be used is "H N L F B".

- 1 -

Hauck Manufacturing Co.
Lebanon, Pa.

Date: 9-7-82

Meeting with John Marino, Vice-President
Sales and Engineering

1. This report deals more specifically with the Hauck Series 780 Burners, with Cup Type nozzle, having catalogue capacity rating range of 0.75 to 200 USgph when operating with air pressures from 16 to 32 oz., with oil pressures (at 100 SSU) of 2 to 8 psi and secondary combustion air provided by natural draft, or forced draft as required.

2. The "special data" sheet S-142AB shows Model Nos. 1943 to 2104, being cup type burners designed for extended ranges from 200 gph to 500 (+) USgph requiring 25-50 psi of steam or air atomizing media.

3. Generally, with the cup design it is only necessary to bring the oil to the cup rim where it is sheared by the atomizing medium.

4. My calculations based on a 500 USgph unit shows an exit oil velocity of a 6 ft/sec. providing a rate of shear of 186. which corresponds to an effective fluid pressure at exit of approx. .2 psi flowing CWM at 1.17 SP.G. (approx.).

5. Photocopy of Hauck Dwg. No. S-142-AB dated 2/1/61 is attached.(Fig.2)

6. In more recent time Hauck have developed their "Jet" burner which extends the capacity range to 1200 gph of oil with a max. vis. of 175 SSU (preferred 100 SSU) and a steam or air atomizing medium of 90 psi.

7. Hauck state that the Jet burner can be converted into the cup type design with, (presumably) shear rates, velocities, and pressures comparable to the series 780 cup type.

8. Photocopy of Hauck Jet Dwg. No. GY1103 is attached. (Fig. 2.1)

9. It should be noted that the 780 cup design Dwg. S-142 AB, has some atomizing air enter Section B of the nozzle to form an emulsion in this section - which then would effect velocity and shear rate at cup rim.

9.1 Enquiry as to amount of air and force of impact on CWM will be made. (See work sheet dated 17-8-82).

9.2 It would seem from the S-142 AB data sheet that "impaction" would be of low value. The cup is small area zone which presumably can be of alloy, or can be flame surfaced with (say) tungsten carbide at relatively low cost.

9.3 The design of the Jet burner to a "cup" type would require a similar emulsion chamber.

9.4 Hauck have stated that the cup design with an emulsion chamber just behind the cup still qualifies the design as an external mixing type because there is no orifice opposing the emulsion.

10. Operating Experience with COM - CWM:

10.1 In the proceedings of the 3rd Annual Symposium on COM -CWM there was a report of a test made in England on COM by a Mr. Moles of the Dept. of Chemical Engineering, Surrey, and it came to be known that the burner was a Hauck cup type unit.

10.2 The hours of operation were not given - but according to the 3rd Proceedings Report, there was "essentially no errosion".

10.3 Hauck also had a demonstration experience on 50% COM with Comco at the General Asphalt Co. in Palmetto, Fla., Report No. S.J. 1046 was written, authored by John Marino and Robert Safarik. Copy of this report is attached.

10.4 This test was not too conclusive, as per report data ,due to poor design of the piping and tracing system.

10.5 The inadequacies of design caused the burner to drip low temperature COM (170°F) and there was no ignition at this low temperature.

10.5.1 However, the moment the COM temperature at burner nozzle increased to the minimum required temp. of 230°F, ignition was established and a stable flame was formed - similar to the flame from burning straight No. 6, though bushier.

10.5.2 The burner was fired at rates from 60 to 24 USgph in a brick lined combustion chamber 42" I.D. x 36" long, with process drum extension of 40" for a total flame length availability of 76".

10.6 Of considerable interest is that the comments of Mr. John Wilda, Mgr. Commercial Development, and of Mr. Jas. Pekor, Application Engineer, both of Comco were essentially the same as Hauck's report with one exception - both blamed the other for the difficulties due to system design errors. Comco confirmed that there was a good flame when the correct fuel temperature was reached.

10.6.1 I felt a compulsion to suggest that one of the contracting parties in a COM test should have on staff, in time, a competent systems designer to set up a fuel conditioning system that would allow the burner and the CLM to demonstrate their respective functions. They agreed.

11. I still think that it would be good to have a trial of Hauck on CWM in a demonstration plant.

12. Addendum:

I am enclosing Dwg. No. GY3407 (See Fig. 2.2) and Brochure No. CA21 on the Hauck Model HMC burner. This is a special process application unit developing gas velocities up to 15,000 ft/min. for maximum convective heat transfer. Hauck are undertaking a test of an 8 million BTU unit in a gypsum kettle in the Johns Manville Celotex Plant in Florida. COM fuel will be provided by COM Energy Co., of Jacksonville (owned by Occidental Oil). See my report on COM Energy Co.

Addendum No. 1
To Report on Hauck Burner,
Dated July 9, 1982

Date: 19-8-82

Discussion with Roy Folland
Hauck Burner Agent for Eastern Canada

1. The 780 Series, shown on photocopies of Pages 1, 2 and 3 1) of Hauck Brochure AA1 (GB410FF) when provided with a "Cup Atomizer" tip, as replacement to the tip shown on the photo Fig. 2 on Page 2 of the Brochure, has an extended range capacity from the 200 USgph of the standard atomizer when provided with induced tertiary combustion air, to a maximum of 500 (+) USgph when provided with tertiary air from a vane controlled F.D. fan.

1.1 Swirl vanes are not provided because, as claimed, they are not needed with the flame pattern established by the atomizing and secondary flows in the basic burner.

1.2 The Hauck Burner Co. (Lebanon, Pa.) are considering the manufacture of a "Package Unit" to include the tertiary combustion air fan.

2. The "Jet" burner, with Cup type atomizer, requires 60% of total combustion air to be provided by a tertiary air fan at approximately 8" to 10" static pressure capability, for a cap. range of 500 to 1000 USgph.

2.1 Swirl vanes are not provided as they are not considered necessary.

2.2 The "Jet" burners and tertiary air fan can be provided as a package unit when it is called the Hauck "Powerflame Burner".

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1) See Section "Figures".

Process Combustion Corporation (PCC)
1695 Washington Road
Pittsburgh, Pa.

Date: 10-7-82

Report on Meeting with
Peter Nutcher, Vice President

1. PCC is a consortium formed by Urquhart Burner Co., of England and Bloom Engineering Co., of the U.S.A.

2. The Urquhart atomizer considered to have the best potential for COM-COW-CWM is the model designated "SFF", - as per Fig.3, so marked, enclosed.

3. Oil pressure at nozzle inlet is only that required to cause oil to flow to the oil orifice, where back pressure from steam atomizing jet streams causes the oil to flow over the "Vortex" cup surrounding the exit orifice.

4. It would seem that there would be little, if any, impaction of the CWM on the cup surface.

5. The atomizer capacity is a function of the cup area, which in turn affects the required steam on air pressure for atomizing. The limit in steam pressure is that due to sonic velocity.

6. Atomizing steam pressure range, according to cup size, is 5 - 100 psi.

7. The sketch code No. "SFF" attached has a 1 1/2" dia. cup as scaled (by Peter Nutcher) and is conversatively rated at 20.10^6 to 25.10^6 BTU/Hr. (See Fig. 3)

8. For,. say a 200.10^6 BTU/Hr capacity atomizer the cup area, based on 25.10^6 BTU/Hr for the 1 1/2" dia. cup, would be eight (8) times the area of the 1 1/2" cup, so that the cup dia. for a 200.10^6 BTU/Hr atomizer would be $\sqrt{8} \times 1.15 = 4.25$ in. dia.
$= 14.2$ sq. in.

9. Fig. 3.1 shows, schematically, the function of the high pressure steam jets creating a back pressure into the vortex cup and forcing the CLM towards the steam exit annulus where atomization occurs.

9.1 A single set of jets is used for the smaller cups. For the large units (say over 3" - 4" dia.), an extra set of steam jets is used to provide a second set of steam stream lines to reinforce the back pressure and atomizing effects described above.

10. Peter Nutcher stated that, in his opinion, the speed of CLM flow over the cup is such that the fuel would reach the atomizing rim with little evaporation and so would still be essentially the same coal liquid mix as provided to the nozzle inlet. (See calculations in work sheets dated 8-8-82).

11. The atomized fuel would be fed into an Urquhart Toroidal Combustion Chamber, where combustion air is provided, as shown in Fig. 3.2.

12. P.C.C. have been approached by Comb. Engr. to provide equipment (free, I believe) for a CWM development program bearing No. PDDA-RD22-81 PC 40295 (My notes are a bit hazy here - the program no. will be checked with Peter Nutcher).

Comco - Subsidiary of Dravo Corp.
Pittsburgh, Pa.

Date: 13-7-82

Meeting with Messrs:
John C. Wilda, Manager Commercial Development
James S. Pekor - Application Engineer

1. Comco is a consortium of: -
    - 1/3 Massey Coal
    - 1/3 Dravo Corp.
    - 1/3 Florida Power Corporation

   Massey Coal is allied to St. Joe Minerals which is owned by:
    - 50% Shell Oil (Dutch Shell Group)
    - 50% Florida Corp.

2. Comco advised that they are:
   a) Active in R & D on CWM, with a variety of mixes being produced.
   b) Active in demonstration programs, E.G. Florida Power Co. - Paul Barlow Station in St. Petersburgh, Florida.
   c) General Asphalt Plant
   Palmetto, Florida
   (owned by Hooker Chemical).

3. Item 2 b) is with Peabody "Bullet" Atomizer using 50% COM. See data in my report on F.P.C.

4. Item 2 c) was a short duration test with Hauck Burner. Comco were disgruntled with the "system" difficulties, due to inadequate design (for which Hauck and Comco blamed each other). I remarked that it would be better to have a competent fuel flow and conditioning system designed and made so that the burner trial would then provide realistic results. Comco agreed.

4.1 Actually Comco admitted that when the required temperature at the burner was attained, that a good flame was obtained.

5. The Hauck burner tested was a standard jet type of 500 gph capacity not converted to the "cup tip" design due to time limit.

6. Comco advised that Fred Martin of Florida Power Corporation (Paul Bartow Plant) would be writing a paper this Fall on COM operation at his Bartow Plant.

7. Comco stated that the whole technology of COM-CWM- was still under R & D, but they expected to have a commercial operation in the Spring of 1983.

7.1 Comco would then call for suitable burners.

8. Comco are currently doing burner R & D within their organization.

8.1 However, they would prefer to purchase "good" burners outside, as their main interest is the CLM fuel production and sale.

9. Comco labour under the illusion that it is up to the burner manufacturers to state his "viscosity" requirements.

9.1 I suggested that it would, in my opinion, be much in their interest to go into the rheology of their products and provide rheograms for study by the burner manufacturer. Only in this way could the "apparent" viscosity and the atomizing experience and flame control become related and so accelerate CLM burner design development.

10. I am enclosing the Comco bulletin entitled "Composite Fuels".

Pittsburgh Energy Technology Centre

Date: 12-07-82

Meeting with Messrs. Daniel Bienstock and Roy C. Kurtzrock

1. Market for COM is slim.

2. Most companies who have been developing a COM or a COW are now working primarily on CWM - because the market for COM is poor (or as Roy Kurtzrock remarked "there is no market" for COM).

3. The major companies doing R & D on CWM are:

a) Atlantic Research Corp., Alexandria, Va.

b) Gulf & Western.

N.B.: Gulf and Western were (or are) producing a COW with 5% - 10% water. They conducted some combustion tests in a plant in Bridgeport, N.J., via the Advanced Technology Co.

c) Occidental Research Co. (Subsidiary of Occidental Oil Co.)

d) Slurry Tech. - Miami, in collaboration with Prof. Funk of Alfred University (Person to contact in Slurry Tech. is Don Dunlop).

B & W are involved in some test work with a CLM from Slurry Tech.

e) Carbogel.

f) Gulf & Western's associated company in Sweden is named Nycol.

4. The R & D done at P E T C was sporadic. The longest run was 500 hours, in a burner equipped with tungsten carbide inserts in the atomizer orifices.

4.1 The tests were carried out at a firing rate of $24-30.10^6$ BTU/hr. in a 25,000 PPH boiler.
The tests were with COM at 50% coal concentration.

4.2 From the test results Roy Kurtzrock estimates a tungsten carbide insert equipped atomizer at a lifetime of 4 months. Assuming a 50% load factor and a 5 day week the hours would be: -

$5 \times 16 \times 24 \times .5 = \underline{960 \text{ hours}}$

N.B.: This checks with the figure of 1000 hours given me by Dr. Ken Olen for the last modified ICL atomizer at FPLC Sandford Plant.

5. Data proferred by PETC on Sanford Com Test.

5.1 Original burner tried was a Clark Chapman (U.K.) now owned by ICL.

5.2 Runs on COM under D.O.E. control lasted 3 days to 3 or 4 months. PETC could not state actual total hours on any one atomizer.

5.2.1 N.B.: Dr. Ken Olen of Florida Light & Power did confirm, after consulting with Sanford, a life of 1000 hours with the latest ICL burner modifications (See remarks FPLC report).

5.3 E.P.A. (?) to support trial of 1 yr. or 120 full power days (2880 hours).

5.4 PETC did not have precise data on % carbon burn-out, but in their opinion, there was no "problem" of carbon in ash. There was carbon in ash after blow-down.

5.5 PETC use the A.S.M.E. test code for efficiency determination.

5.6 Experience has shown that atomization requirements on COM can be based on the viscosity of the #6 carrier oil. Then the desired viscosity is a function of the temperature/viscosity characteristic of the particular #6 oil used in the COM.

For calculation of piping pressure drop, however, it is my opinion that the viscosity value used should be that shown on the graph in the rheogram which gives the "apparent" viscosity in relation to shear rate (a pipe design factor) at a given flow temperature, and at a given coal concentration

6. Work by Florida Power & Light Co., in CWM research is not subsidized by D.O.E. It is strictly FPLC funding.

7. P E T C is now starting R & D on CWM.

8. I questioned Dan Bienstock on the rheograms shown on Fig. 3 of his paper,(1) co-authored with Edward M. Jamgochian and he confirmed that: -

8.1 The viscosities were uniform down to a shear rate of 10 (sec^{-1}).

8.2 There was need of keeping velocities in a given pipe dia. above a shear rate of 10 sec.$^{-1}$ to avoid pressure and flow irregularities if the flow entered the sharp rise portion of the rheograms. Fig. 3 of the paper (1) shows that this applied to COM coal concentrations of 30%, 40%, & 50% by weight in a No. 6 oil at 60°C (140°F).

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(1) "Coal Oil Mixture Technology" by Daniel Bienstock and Edward M. Jamgochian presented at the Industrial Carbons Graphite Group of the Chemical Industry at the Society of Chemical Industry, 14 Belgrave Square, London SW1X 8PS - April 7 - 9, 1981.

9. Table 1 below shows the calculations, I have made for minimum flow velocities, and the corresponding minimum BTU flow in various pipe sizes.

Table A

Minimum Velocity & BTU Flow Required to keep shear rate above 10 (sec^{-1})

Pipe Dia. Nominal, Ins.	Minimum Velocity, ft/sec	Minimum BTU Flow(2) 10^6 Hrs.
1.5	0.625	35.5
2	0.83	78.0
3	1.25	258.0
4	1.67	590.0
6.	2.5	2020.0

(2) Based on mean value of 179,000 BTU per Imp. Gal. COM, with coal concentration by weight ranging 20% - 50% coal heating value - 14,000 BTU/lb.
No. 6 oil heating value - 180,000 BTU/Imp.Gal.

Fuel Development Group
Pittsburgh, Pa.

1. No answer to telephone call.

2. P E T C had advised that this was a small (two (2) man) "entrepreneurial" outfit.

2.1 They added the name Pomerance to the name I had on my list - Guy Leighton.

National Air Oil Burner Co.
Philadelphia, Pa.

Date: 14-7-82

Meeting with Gordon B. Bitterlick
Vice-President & Chief Engineer

1. Detailed drawings and brochure sheets showing construction and function of the N.A.O. type S A burner are enclosed.

2. This burner is a steam-oil emulsion type capable of burning refinery low grade refuse fuels.

3. As noted in the brochure descriptive data, oil flow is at low pressure, assisted by the injection effect of the steam nozzle (under certain circumstances gravity fuel flow is possible). The fuel pressure range is zero to a maximum of 100 psi.

4. Figs. P738-739 on Page 2 of the brochure material indicates that one of the CWM wear points could be in the fuel annulus surrounding the steam injector.

4.1 However, considering the low oil pressures and consequent low velocities, possibly inexpensive alloy material or flame coating with a suitable alloy, of the side of the annulus surrounding the steam nozzle, could result in satisfactory life.

4.2 The pressure capacity data shown in the Table on Page 9 of the brochure material, indicates that the combination of steam injection effect and oil pressure (at control stand) provides for oil flow directly proportional to the oil pressure.

4.3 Therefore R & D could determine the steam pressure/fuel pressure relationship versus rate of flow, and resulting emulsion velocity.

5. The orifice shown in the drawing and in the brochure photos is for a flat flame.

5.1 However, Mr. Bitterlick advised that the atomizer head can be made with multiple orifices. As these orifices would flow an emulsion the effective fuel velocity, i.e.: its erosion factor could possibly, be low. Consideration of tungsten carbide or ceramic inserts could add to further life.

N.B.: The B & W Model "T" atomizer and the Hauck cup burner design also use an emulsion principle- steam -oil for B & W and air-oil for Hauck.

6. Dwgs. enclosed Nos. M-215-3; M-216-3, M-227-3 and M-219-3 detail the components of the burner atomizer. Burner Dwg. No. M-211-5 shows their assembly into a complete burner atomizer.(See Report Figs.4-4.5)

7. I gave N.A.O., a copy of the confidentiality protection document to cover the confidential drawings given to me.

8. An example of Multiple Jet Orifice design of the size H3 burner atomizer is one with 24 - 1/8" orifice for a total exit area of approx.-30 sq. ins., or .002 sq. ft., for a flow rate of 240 USgph (tentative max.) and a corresponding velocity of approx. 4 1/2 fps (CWM vel. only) or 335 fps for the (1) emulsion (with 100 psi atomizing steam and 50 psi emulsion chamber pressure. Size and number of jet orifices can be varied and single orifice can also be provided.

8.1 Atomized fuel spray angle can vary from 30° - 90°. The single orifice round flame tip can be provided to give a short bushy or long flame.

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(1) See work sheets dated 24-8-82 showing "effective" emulsion velocity of 4.5 fps based on CWM/steam volume ratio.

8.2 The role of a forced draft register design to provide flame control is not mentioned in the enclosed literature.

9. National Air Oil will be willing to provide tips of various sizes and drillings for R & D.

10. N.A.O. had a F.D. register burner with vanes. N.A.O. do not now manufacture such a register but they believe that their S.A. burner can be adapted to any circular register with single or multiple adjustable vanes.

11. It occurred to me that since oil in Chamber C (Fig. P-739, Page 2 of brochure material) had to take a 180° turn to enter the annulus surrounding the steam nozzle BD, that this might cause some deposition of coal.

12. On probing this point with Mr. Bitterlick, he considered that it would be possible to change the oil and steam entry configurations, i.e.: to have the oil enter along the horizontal centre line, and to have the steam entry port at 90° from horizontal centre line.

Faber Burner Division of
Keeler Dorr Oliver Co.

Date: 10-8-82

Meeting with Mr. Gilles Babin
Manager Steam & Industrial Equipment Co.
Dorval, Québec and telephone conference with
Dave Cron, E. Keeler Co., Faber Burner Division Engineer

1. The Faber Burner with potential for CWM is a steam atomizing internal mix burner with capacity range of 200 to 10,000 lbs. oil per hour.

1.1 Operational data are given in Tables 1 and 2 enclosed.

2. Faber have test fired 50% COM with good results using their standard steam atomizing burner, with nozzle in 416 stainless steel.

3. A 150 USgph rated capacity unit was used firing into a 17,500 PPH rated "D" furnace package boiler.

4. Flame characteristics were equal (or better) than firing of No. 6 fuel oil.

5. The atomizer was designed with 10 #25 orifices having a total area of .1750 sq. in.

5.1 At 150 USgph the exit velocity is approx. 4.6 fps (CWM only).

5.2 The atomizing steam at burner inlet was: -
100 psi and the consumption was 1% of boiler output,
or approximately .15 lb. atomizing steam per lb. COM.

5.3 There was no side wall impingement.

6. COM test consumed 6000 gal. at a 100 USgph firing rate or a cumulative operating time of 60 hrs.

7. Dave Cron reported no appreciable wear in the 416 stainless steel atomizer.

8. In addition to the 17,500 PPH test boiler of "D" furnace design, Faber also have a "firing tank" suitable for testing burners up to 10,000 lbs./hr., firing rate.

9. Faber are willing to do R & D work using their facilities, under suitable business arrangements.

10. Faber are considering some "exotic" alloy atomizer, but Dave Cron was dubious about their ability to handle tungsten carbide or ceramics as inserts.

11. Faber will be conducting a burning test on CWM in the first week of September. This initial test will be short - consuming about 300 US gals. with a burner firing at 40 - 50 gals/hr, or a total test time of 6 - 7 hours. The atomizer on this test will be made of their standard 416 stainless steel.

12. Dave Cron was uncertain as to source of the CWM but believed it might be supplied by B.P. (Mr. Morton, Gen. Mrg., would know. He will be back from holidays August 23rd.)

Atlantic Richfield Oil Co.
Newton, Pa. (15 kl. from Pittsburgh)
Date: 12-7-82

1. Spoke to Dr. Pat Ryan at ARCO office, Newton, Pa.,(telephone for Dr. Ryan is (215) 359-2106),Head of Chemical Division of ARCO and he referred me to the following parties who were involved in CLM R & D.

Frank Chlonpek - Harvey, Illinois, Tel. (312) 333-1483.
John Siemsen - Los Angeles, Ca., Tel. (213) 486-0941.

2. Dr. Ryan himself is not involved directly in CLM R & D except where chemical problems would require his attention.

3. In cases where ARCO are working under subsidy from EPRI, it would be necessary to first contact EPRI.

4. Bob Thomson had advised that Atlantic Richfield were the prime contractors for EPRI under Contract CS-2-509-Vol. 1.

Project No. 1458-2

This work was done by Bechtel & C.E. Inc. & final report was given to Atlantic Richfield in May 1982.

5. Messrs. Chlonpek and Siemsen will be contacted by telephone to determine what information I could obtain from them on the above research, and whether approval of EPRI was first required (particularly in view of the DSS confidentiality document).

Niro Atomizer Inc.
Columbia, Maryland

Date: 18-7-82

Meeting with Mr. Sten Mortensen
Manager, R & D

1. The Niro Atomizer atomizing wheel design incorporates a bushing of Tungsten carbide and is used in the spray drying of ceramics, ore concentrates and other abrasive slurries.

2. A protective coating of the abrasive material is built-up on the inner surface of the atomizing wheel, which then can be made of stainless steel. "Long operating lives" are claimed.

3. The atomizer wheels are from 7 to 9 in. O.D., and operate at speeds of 8000 to 9000 r.p.m., at times up to 15,000 r.p.m. Abrasive material slurries up to 77% concentration have been used.

4. The Niro atomizer also successfully atomizes a calcium carbonate slurry in a boiler exhaust gas SO_2 removal system.

5. Copies of Niro Atomizer Bulletin B-Na#191 and a single page extract from Bulletin B-Na-222/HS - show the operating features of the atomizer.

6. I learned about Niro from Allis Chalmers who referred me to the Niro associate Joy Manufacturing Co., with offices at 970 Montée de Liesse, Ville St. Laurent, Québec H4T 1N1, Tel: 337-2215.

7. Mr. Stafanoni - Sales Manger, in St. Laurent, was at first skeptical of the thought that the Niro atomizer could be used in the horizontal mode, equipped with burner aerodynamics and so made into a burner suitable for CWM. He thought a Niro coal spray dryer might prove to be the answer to CWM.

8. Mr. Stefanoni referred me to Niro Atomizer Inc., plant in Columbia, Maryland, and gave me a number of names to contact, which led me to my meeting with Mr. Sten Mortensen, newly arrived from Copenhagen to take charge of R & D in the U.S. plant.

9. Mr. Mortensen could see no vital reason why the Niro Atomizer could not be operated horizontally, provided suitable mechanical design changes were made.

Also, he saw no great difficulty in designing for the combustion air supply.

9.1 ACTUALLY, Niro in Copenhagen are under contract to a customer for the R & D work to develop such a unit for the burning of CWM.

9.2 Patent rights would be held by Niro.

9.3 It was possible, said Mr. Mortensen, that Niro would be agreeable to a mutual R & D effort in Canada.

10. I questioned Mr. Mortensen on the use of a Niro Spray Dryer to dry a 70% coal-water slurry and a system to convey the resulting dry coal to P.F. burners on a utility boiler.

10.1 Fig. 10 is a sketch by Mr. Mortensen of such a system, and which shows the need of 0_2 control in the drying process.

11. Mr. Mortensen will develop data on the maximum capacity of such a system and a "guesstimate" of the cost per unit of capacity, and he will advise me on these points.

12. He will also advise (with discretion) on the development of the Niro CWM burner which is now in progress in Copenhagen.

- 1 -

Atlantic Research Corp.
Alexandria, Va.

Date: 18-7-82

Meeting with Dr. E. T. McHale
Technical Director - ARC-Coal

1. The present prime interest of ARC is the production of a successful CWM.

2. At the start of their research they found that the Commercial burners which they tried were not successful, particularly in terms of atomizer.

3. To prove capability of CWM use they developed a single copy of a burner as per sketch by Dr. McHale, attached. The calculation, for fuel velocity was 1.93 fps at an operating rate of 10 USgph as noted on the sketch.

4. As shown by the notes on Dr. McHale's sketch, the minimum atomizer air gap to produce a symmetrical flame was 10-15 mills. Smaller gaps produced flame pattern distortion.

4.1 Should smaller atomizing gap be required with certain CWM, more precise (expensive) machining would be required.

5. Their first CWM plant was a small field plant of 2 barrels/day capacity.

6. A sample was provided to the Florida Power & Light, Long Island Plant.

7. Atlantic Research are currently developing a 600 bbl/day plant for larger scale tests in 1982.

7.1 They intend to have some test runs of 30-60 days.

8. Atlantic Research have conducted a research program for the D.O.E., Pittsburgh Energy Technology Centre under Contract No. ACOL-77-ET-3041.

8.1 Their report on Phase II - Combustion Studies was submitted in May 1980.

8.2 Copies of pages 1-14 inclusive, of this study, being relevant to this report, are attached.

9. Fig. 3, Page 8, of Dr. McHale's report shows the ARC burner design in greater detail, and the drawing shows the schematic of the variable swirl secondary air. (This drawing is Fig. 6 in this report.)

10. Photocopy of a further paper by Dr. McHale, et al, published in Combustion & Flame, issue No. 42 (1982) is enclosed in its entirety.

10.1 There seems to be an anomaly between the values of columns 2 & 3: slurry flow rate (lb./hr.) and firing rate (MMBTU/hr.) in Table 4 of this second paper.

11. Data on the ARC burner parameters and its operating characteristics are given in Table 1 of this report on CLM burners (E.M.R.).

Atlantic Research Corp.
Alexandria, Va.

Date: 20-09-82

Addendum No. 1 to Report dated 18-07-82
Telephone discussion with Dr. E. T. McHale

1. Maximum capacity of first (and only to date) burner design is 10 USgph.

2. Test data was obtained at a firing rate of 1.10^6 Btu/hr.

3. Consideration is being given to a larger burner design by increasing dia. to $2\ d_1$ (d_1 = present burner - See Fig. 6) to give 4 x area and so 4 times flow rate for same flow velocity.

3.1 A limiting factor in further increase of the diameter of the nozzle will likely be the ability of the atomizing fluid to penetrate the entire fuel stream.

3.2 Dr. McHale believes it may be necessary for him to consider a divergent nozzle, comparable to the designs of ICL, Hauck and Urquhart.

4. The ARC burner can burn straight fuel oil #2 to #6.

5. The ARC development in CWM is progressing well and they expect to be in some degree of commercial production in 1983.

6. Viscosity data on their CWM will be provided to prospective users from data obtained from the operation of test loops, with varying pipe sizes and flow velocities, rather than from Brookfield Viscosimeter tests.

6.1 They expect to publish such data in 1983.

Pillard Inc.
Richmond, Va.

1. I had been advised by Mike Howlett of Industrial Combustion, Dorval, Québec, that Pillard burners were of the mechanical pressure atomizer type requiring 400 - 600 psi for an exit velocity of 189 fps to 231 fps (fuel only).

2. Much evidence indicates that this burner type may be unsuited for CWM.

3. Therefore, I overflew Richmond to save a day.

4. However, I will contact them - if so directed.

5. Enclosed are burner design drawings, Figs. 7 and 7.1.

Eastern Seaboard Petroleum Co.
Jacksonville, Florida

Date: 21-7-82

Meeting with Dwight Bender
R & D Engineer

1. Eastern Seaboard operate under their logo "Emulsofier". They are a subsidiary of Ashland Oil Inc.

2. They provide a water-oil emulsification system under the trade mark "Emulsofier", under the patent of Roy Folland, Commix Inc., Consultant, Main Street, Hudson, Québec, Tel: (514) 458-7011.

3. All operating characteristics of the emulsifier water-oil emulsion, regarding pressure, viscosity, atomization, flame dimension control, are much the same as for the parent No.6 fuel oil.

4. No. 2 fuel oil cannot be emulsified because the product would be unstable as separation would occur.

5. The max. viscosity of No. 6 oil that can be used to make the emulsion is 750 S.S.U., though a lower viscosity is suitable.

6. Enclosed is a photocopy of a paper by Taback & Taplin providing general data on "water-oil emulsion" firing.

7. A further and more detailed paper by Roger Nesbitt will be found in the Georgia Pacific Pulp & Paper report. The operating results on use of the Emulsofier in a 100,000 PPH package is described, and some interesting comments are made, under the paragraph heading "Operating Fundamentals", on the control requirements of the unit needed for successful operation.

8. Should COM or COW be found intractable because of capital cost, de-rating, problems of slagging and fouling in a boiler designed for oil firing, then, in my opinion the virtues (and vices if any), of the Emulsofier water emulsion system may well warrant investigation.

- 1 -

COM Energy Inc.
Jacksonville, Florida

Date: 21-7-82

Meeting with Michael Sharkey
Plant Manager

1. Owned by Occidental Petroleum Co.

2. Plant Manager - Michael Sharkey.

3. Date seen - 21-7-82.

4. Mike Sharkey has no operating experience with any burner.

5. Plant in stage of final completion of capacity increase.

6. Rheology, i.e.: Rheograms of COM, if any, in hands of Occidental Petroleum (or others).

7. They have provided COM for trial by burner manufacturers who, presumably, will determine the rheogram and coal characteristics of the COM, essential, in my opinion, if they are to design a flow system and evaluate burner performance re:
   atomization; flow control; atomizer life; carbon burn-out; flame control; etc.

8. COM Energy Inc., are undertaking a test with a Hauck Burner (1) at Celotex plant of Johns Manville, near Jacksonville. Occidental, et al are involved in this test.

9. For results of tests made since plant production started in September 1981, see Vol. 2, Section IV of "Proceedings Fourth International Symposium on Coal Slurry Combustion" - May 10-12, 1982 - Orlando, Florida, in article entitled "Commercial

9. (Cont'd) Production and use of Coal-Oil Mixtures by: -

E. Knell - Occidental Engineering.
D. Adam - Island Creek Coal Sales.
T. Greshaw - COM Energy.
I. Dickson - Hooker Chemical.

10. It will be noted that in one test an existing Coen Style MV - internal mix steam atomizing burner was used, modified for the higher viscosity and abrasiveness of COM fuel.

10.1 Data on atomization, flame characteristics, atomizer life, carbon burn-out are not given in the referenced report.

11. COM Energy Inc., have developed a portable testing plant to test various burners.

12. N.B.: (Confidential - off record) - Mike Sharkey did state that he had experienced stability problems (settling) and some flame "disturbance".

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(1) John Marino, Vice-President of Hauck Burner Co., has confidentiality document. I will contact him in the next few months for results of test at Celotex.

Georgia Pacific Pulp & Paper Co.
Palatko, Florida

Date: 21-7-82

1. Spoke on phone to Roger L. Nesbitt, Manager of Power and Recovery, just as he was leaving town for sometime.

2. He was interested in CLM fuels and would have been glad to give me an interview.

3. The plant is actually using an oil-water emulsified fuel, provided by Ashland Oil Inc., via their subsidiary, Eastern Seaboard Petroleum of Jacksonville, Florida, under their logo name "Emulsofier" (See my report under the title "Eastern Seaboard Petroleum".)

4. Enclosed is a copy of a paper by Roger Nesbitt reproduced from Tappi, which describes the results of application of "Emulsofier" to a pressurized 100,000 PPH, 400 psi, 700°F packaged boiler in the Georgia Pacific Plant.

Florida Power & Light Co.
Juno Beach Office - Florida
Re: Sanford Utility Plant
Date: 22-7-82

Meeting with Dr. Ken R. Olen
R & D Scientist

1. The experience at the Sanford Power Plant is with 40% - 50% COM.

2. With the latest modified ICL burner, they have experienced an atomizer life of 1000 hours using tungsten carbide. (ICL is located in Derby, England).

3. This burner is of the external mix design and is the most promising of the types tried at Sanford.

4. All data, in detail, are confidential to I.C.L.

5. Dr. Olen's opinions on alloys for atomizers, given to me, are:-

5.1 Ceramics, high carbon stainless, and certain other materials can suffer thermal shock.

5.2 Rejection factor with ceramics is volume loss rather than weight loss.

5.3 Life expectancy of alloys:
    Iron Boride - -2 x tool steel.
    Tungsten Carbide ->2 x tool steel.

6. F.P.L.C. is starting R & D on CWM and expect that the R & D time to point of success in Utility plants will be about three years.

7. Slagging is a problem with COM, The oil ash has synergistic effect on the coal ash, lowering the ash softening temperature.

7.1 Adding water to the COM increases the ash softening temperature and produces a friable ash adhesion on boiler tubes.

8. The Central Electricity Gas Board of England are producing a new burner.

9. The International Flame Research Foundation at Ijmuiden, Holland, have developed a COM burner of the Internal mixing type.

10. Some of the U.S. utilities and EPRI are sponsoring Battelle and M.I.T. in R & D.

11. M.I.T. are involved in working on COM and CWM R & D with two different atomizers. The firing rate is 3.10^6 BTU/Hr, in a 10.10^6 BTU/Hr. combustor.

12. The scale up of design of atomizers presents problems of aerodynamics and swirl number. Also as firing rate increases above 4.10^6 BTU/Hr., air preheat is required.

13. To secure flame stabilization O_2 enrichment in the amount of 5% by weight of the fuel fired has been found useful.

14. Swirl number is critical with CWM.

15. The firing of CLM in a utility boiler requires, essentially, a base load because:-

15.1 De-rating with CLM - means use of oil only when M.C.R. is required.

16. The target for atomizer design is a life of 2000 hours.

17. Dr. Olen's chief is Dr. J. Uhrig.

Florida Power & Light Co.
Juno Beach Office - Florida

Date: 22-8-82

Addendum No. 1 to Report dated 22-7-82
Telephone discussion with Dr. Ken R. Olen

1. I phoned Dr. Olen to obtain the velocity of the COM from the single exit port of the ICL atomizer (Steam atomization is external).

2. Fig. 10, enclosed shows the dimensions and general arrangement of the atomizer for a 200.10^6 BTU unit.

3. The heating value of the 50% COM used at Sandford is derived as follows:

H.V. Coal	12,000 BTU/lb.
H.V.#6 Oil	18,000 BTU/lb.
SP.G. of COM	1.16
Wt. of COM per Imp.Gal.	11.6 lb.

Wt. of COM per US. Gal. $= \frac{11.6 \times 5}{6} = 9.67$ lbs.

H.V. of Coal/lb COM $= \frac{9.67}{2} \times 12,000 = 58,020$ BTU

H.V. of #6 Oil/lb COM $= \frac{9.67}{2} \times 18,000 = \underline{87,030}$ BTU

H.V. of 1 U.S. gal. COM = 145,050 BTU

3.1 U.S. gals. of COM/sec. is:

$$\frac{200.10^6}{145050 \times 3600} = .383 \text{ US gals.}$$

3.2 Vol. of COM/sec. is:

$$\frac{.383}{7.5} = .051 \text{ Cu. ft./Sec.}$$

3.3 Area of atomizer at shear point (ref. Fig. 10):

$$= \frac{(1.18)^2}{(\ 2\ )} \times \frac{\overline{II}}{144} = .0076 \text{ sq. ft.}$$

3.4 Velocity at shear point is then:-

$$\frac{.05}{.0076} = 6.75 \text{ fps}$$

4. Other information proferred by Dr. Olen is as follows:-

4.1 C.E. & Forney are in trial stage or planning tests on CWM with burners rated at $30.10^6 - 50.10^6$ BTU/Hr.

4.2 Prof. John Beer at M.I.T. recommends the use of staged combustion on CWM to increase: ease of ignition; turn-down; and burn-out.

4.3 B & W may be the first to have a fully commercial burner.

4.4 B & W under the sponsorship of E P R I and Exxon, will be testing 4 or 5 burners rated at 20.10^6 BTU/Hr., in industrial boilers for the Dupont Co.

4.5 B & W will be testing burners rated 10.10^6 BTU/Hr in opposed firing in their combustion test facility.

4.6 The B & W burners to undergo test will have multi-level adjustable vane registers and their "T" model atomizer.

4.7 C.E. have developed a CWM front fired burner which they will adapt to fit into the corner firing configuration.

4.8 Mr. Manfred of E P R I is reported to have said that the Coen Burner Co. is working on CLM applications (COM or CWM - or both - ?).

4.9 Because of reduced ash problems, the smaller jobs may stick with COM-

4.10 Water-Oil emulsions may succeed in improving overall boiler efficiency in some cases, but care must be taken in the operation and maintenance of the emulsifying system.

4.11 Forney are testing one (or more ?) of their burner designs on CWM using dual registers, with air temperatures of 220° F at cold start and 180° F at operating conditions.

4.12 I.C.L. are currently testing burners rated $4\text{-}5.10^6$ BTU/Hr., on CWM, relying on their refractory quarl for flame stability.

4.13 B & W do not use a refractory throat.

Date: 24-09-82

Addendum No. 2 to Report dated 22-07-82
Telephone Discussion with Dr. Ken Olen

1. Ken Olen confirmed combustion air temp. is 550°F at Sanford COM operation.

2. From a paper by B & W - "Rheology & Combustion Characteristics of CWM" authored by Mr. R. Ghassemzadeh - et al, American Flame Research Committee, Chicago, Ill., October, 1981, it was shown that the relationship between % V.M. and combustion air temperature required for flame stability is:

VM %	Combustion Air Temp. % F
29.4	500
24.0	600
20.8	700
13.1	800

3. Ken Olen's overview report indicated plugging in COM with the I.C.L. burner. This occurred only on a lab scale test when the internal passage was 13 mm. of .512 inch.

4. I.C.L. seem to have succeeded in burning CWM.

ADDENDUM NO. 3 - SECTION 16

Florida Power & Light Co.
Juno Beach Office - Florida

Date: 5-10-82

Addendum No. 3 to Report dated 22-07-82
Telephone Discussion with Dr. Ken Olen

1. Ken Olen has a good appreciation of the Forney Burner's potential for success with CWM.

1.1 My interpretation of the Forney atomizer from Ken Olen's description is shown in Fig. 1 attached. This, of course, will be checked with Forney when I see them in Dallas, Texas.

2. Ken stated that the C.E. (Windsor, Conn.) burner for CWM was developed primarily for corner (tangential firing).

3. When front fired in a test furnace (Combustion) at a rate of 50.10^6 Btu (552 USgph for a 70/30 CWM) the flame dimensions, as observed by Ken were 6' - 8' dia. x 25' long.

3.1 I suggest that there could be problems with this flame size in a standard 50.10^6 Btu water tube boiler package.

3.2 The use of multiple vanes, providing a high swirl number, requiring high tangential velocity, and relatively high static pressure fan capability seem to be indicated.

4. According to Ken, from his interpretation of what he had seen at the Windsor meeting, C.E. had not yet done development work on front firing design for CWM.

5. The CWM used in the C.E. trials (according to C.E.) was supplied by Gulf & Western, and had a viscosity of 1500 centipoise (approx. 5850 SSU) at a shear rate of about 100 $\sec.^{-1}$.

.../2

5.1 He understood that the "parent" coal for the new Chatham trials would be from a C. B. D. C. Mine (actually the Prince Mine coal) made. into a CWM by the Carbogel formula by C.B.D.C. as licensee.

6. In a recent attendance at a coal conference in Pittsburg, the comparative emissions of an SRC and a "good quality" #6 oil versus the relative pollution control needs by precipator and a "comparator" (side stream with a "junior" baghouse)was discussed.

6.1 The emission was low.

7. Ken voiced protest over the "inanities" of the proceedings because if CWM (or a CLM) was to be economically viable, a multi-million dollar expenditure on precips and/or baghouse must not be required. (I presume that Ken inferred that a cyclone - or other relatively low cost collector - should be the most required).

8. In referring again to the C.E. demonstration (at Windsor) he stated that the combustion air temperatures for corner firing were:

Inner Plenum ----------------------------------200°F
Upper & Under Air Boxes -----------------------500°F

9. In Ken's opinion I.C.L. (Peter Beal) were "piddling" with CWM R & D, using firing rates of only 5.10^6 Btu/hr.

10. In the observed C.E. test the atomizing pressure (air/steam-?) was 200-350 PSI with an atomizing fluid consumption of .18 lb/lb fuel.

11. There was no data on % O_2, or % carbon burn-out in the C.E. test.

12. Ken Olen is considering asking Rolf Manfred of EPRI for the videotape of the C.E. - CWM corner firing demonstration.

.../3

13. With respect to % boiler de-rating in oil designed boilers Ken considered the main factor would be the limitation of I.D. fan capacity versus the fouling factor in the boiler convection passes.

14. He expects the coal designed boilers at Chatham to achieve good output.

15. Ken Olen further advised that TRW* and G.E. were trying to develop two stage combustion with the first zone providing a reducing function. (low No_x - ?).

15.1 They (TRW and G.E.) are looking for funding for a 50.10^6 Btu/Hr. trial in a demonstration unit.

16. Trials on MagnetoHydroDynamic (MHD) energy conversion system hadn't demonstrated the practicality of this system.

17. FPLC intend to experiment with Carbogel CWM based on an "Eastern Canadian Coal" in a lab trial at a firing rate of $.6.10^6$ to 1.10^6 Btu/Hr.

18. Finally, Ken Olen said that comments by him could be quoted in a report by reference to a "letter communication".

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* TRW is the present legal name of the company once named Thompson-Ramo-Wooldridge.

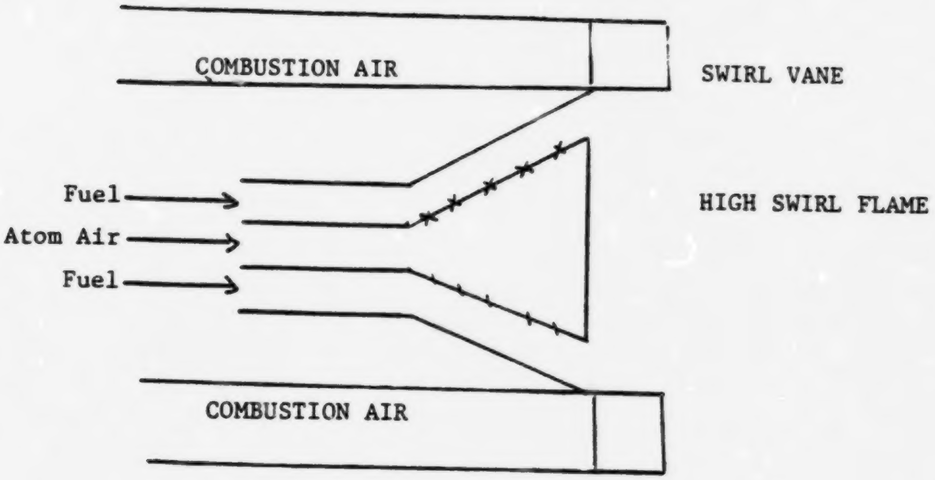
COMBUSTION AIR
SWIRL VANE
Fuel
Atom Air
Fuel
HIGH SWIRL FLAME
COMBUSTION AIR

FIG.1 (1)

Forney CWM Atomizer Design as interpreted from verbal description by Dr. Ken Olen (Florida Power & Light Co.)

(1) See report on Fooney Engineering for actual design.

FLORIDA LIGHT AND POWER CO.
Juno Beach Office - Florida

Date: 16-3-83

Addendum No. 4 to Report dated 20-02-83
Meeting with Dr. Ken Olen at Juno Beach Office

1 The purpose of this meeting was to secure advanced new thinking & operating facts on CWM, acquired by Ken olen since my last contact with him on Oct. 5, 1982 (Addendum 3).

2 The emphasis on current research on CWM was on the atomization function determining coal size distribution and MMD as a function of a) grind to 100% through 200 mesh, b) air and slurry temperature, atomizing air/fuel ratio (see Fig. 5 of EPRI Report entitled "Coal-Water Slurry as an Alternative Fuel"(1) by Rolfe Manfred - (copy of Fig. 5 attached to this Addendum No. 4).

3 In addition to C.E. (Windsor, Conn.) & M.I.T., FPLC & a group of north-east states utilities are involved in this atomization study. (The question of atomizing fluid velocities and type of mixing with CWM fuel in atomizer, and atomizer life, were not brought up at this meeting).

4 Ken Olen considers that heat convection to water droplet enclosing fuel particles was better than radiation to "burn-off" water because: a) water droplet is transparent to radiation causing coal particles in core of water droplet to be heated preferentially, causing an increase in agglomeration of the particles.

4.1 There is a tendancy (in some coals) for fine ground particles to agglomerate within the water globule.

5 The conversion by a utility to CWM requires the availability of a "good" CWM fuel from suitable source or sources, to meet the utilities total fuel requirements.

(1) Presented at Coal Technology '82, Houston Texas, 9 December 1982.

6 When such a source, or sources have been developed, then the utilities and research centres involved with CWM development and use will call upon a number of CWM atomizer manufactureres to submit technical data on the atomising capabilities of their units, including information on a) atomizing pressure; b) atomizing fluid/fuel ratio; c) particle mmd and size distribution using laser techniques .

7 In this regard (Item 6) I put forward the following considerations:
a) because of the cost, would not the research and testing be limited to the few wealthy manufacturers?
b) If scenario a) is correct would it not be more productive to the motivation of a sufficient number of involved manufacturers, to set up a subsidized test facility (say involving EPRI, PETC, Canmet, M.I.T, N.R.C and the utilities) to invite submission of atomizers for testing by the manufacturers of the more promising designs?

8 Ken Olen has a patent (or patent pending) on an explosive additive to a CWM to disintegrate the agglomerated coal in the water droplet.

8.1 A comparable result could perhaps be obtained by heating water over 250°F and securing flash steam. However if the CWM is a body or agglomerate of coal held within a water globule, the resultant flash steam pressure could result in an "implosion" effect and so aggravate agglomeration instead of causing disintegration of the coal particles.

9 Ken Olen applied divergent nozzle (cup) principle to the COM ICL atomizer and obtained improved operating results.

10 Ken Olen and the ICL people were to meet shortly (as of March 16/83) to discuss ICL's CWM atomizer.

11 Ken Olen had doubts whether the N.R.C. ceramic would not crack when made in large sections.

- 1 -

Florida Power Corporation
Paul Bartow Plant
St. Petersburg, Florida (near Weeden Island)

Date: 23-7-82

Data from Short Talk with
Fred Martin, Plant Manager

1. The first burner to be tried on COM was a standard Peabody steam atomizing "Bullet" atomizer model.

1.1 The burner atomizer had a "short" life.

2. Fred Martin instigated a change in which the COM and atomizing steam flow paths were reversed, with improved results.

3. It was not possible to obtain precise hours on operating time, or atomizer life expectancy, because the COM trials were started only about 2 months ago (May 1982).

4. FPC intend to experiment with ceramic or tungsten carbide (or other) inserts in the atomizer exit ports.

5. Further data, on the burner and its operation was provided by Jerry Waldo, Plant Engineer - See Tables 1 & 2.

6. The modified Peabody gun was used with the original B & W pulverized fuel register.

7. Pumps, control valves, safety shut-off valves, etc., were taken from the F.P.C. Crystal River Plant which is now on pulverized coal firing.

8. Enclosed is a paper by Michael E. Higgins, Technical Services, Supt. of F.P.C., on the Conversion of the Bartow Plant to COM.

FLORIDA POWER CORP.
Addendum No. 1

to Report Section No. 17 dated 23-7-82

Phone discussion date: 26-9-83 Michael E. Higgins
Technical Services Superintendent

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1. In my 1982 visit to the Paul F. Bartow Plant, Weeden Island, St. Petersburg, Fla., I was able to obtain only limited information, particularly because they had been on COM for only 2 months on Unit No. 1 and they were experimenting with modifications of the Peabody "Bullet Atomizer".

2. There are two technical papers in the Fifth Symposium on Coal Slurry Combustion, of 1983. On the Paul Bartow Plant COM developments. One paper is by Michael Higgins and the second by Michael Higgins and James Dudley. Actually the modified Peabody Bullet Atomizer is a "Dudley-Higgins" design.

3. In our hour's conversation Mr. Higgins was very cooperative in offering me much information and answering my numerous questsions, and I am able to report as follows.

4. The initial operation was with a modified Peabody Atomizer in which the fuel and atomizing steam flows to the emulsion chamber were reversed.

5. Initial life time was 10-20 operating days which represents 130 to 260 hours at a load factor of 54%. The material was tool steel.

6. Experimentation continued with various arrangements of exit orifices for size, number, diameter, and centre line angle with respect to the longitudinal axis of the burner.

7. They ended up with a unit that provided a flame holding well within the furnace dimensions and with an operating life increased to 4-6 weeks and still using tool steel.

7.1 The life in hours in current operation between atomizer changes at 54% load factor (assumed) with tool steel metallurgy is then 363 to 544 hours.

8. In the modifications by Florida Power Corp., the atomizer exit orifices were provided with removable inserts.

9. Tungsten carbide was considered for the inserts for an estimated increased life up to 30 weeks or 2721 hours, but requiring experimentation for confirmation of the actual hours possible with such tungsten carbide inserts.

10. There are 8 orifices each in each atomizer of a dia. of 0.266" or a total of 0.037 sq. ft. for 12 burners.

10.1 Then at a 50/50 COM fuel emulsion flow of 3.84 cfs. the max emulsion velocity is 630 fps.

10.2 With fuel/emulsion ratio of $\frac{.32}{.32 + 23} = 0.0137$

the effective velocity (theoretical) is:

$0.0137 \times 630 = 8.6$ fps.

10.3 Add effect of angle of incidence

$\text{Sin}^{-1}\ \underline{35^\circ}$ $\underline{1.75}$

Then the

10.4 Erosion index is: $\underline{10.35}$

11. F.P.C. do not consider that the cost of T.C. inserts is economically acceptable.

12. With only 12 burners they find that 2-3 burners can be pulled in a shift, examined, and atomizers changed if required.

13. No load or personnel problems arise. (Burner change is done on low load hours.)

14. The boiler was designed as a tri-fuel boiler, i.e. pulverized coal, oil or gas.

15. There are a number of technical factors that throw light on the atomizer performance - as follows:

16. The COM is purchased from FPC subsidiary COMCO. It is thixotropic and no additives are added.

17. The coal is ground to 95% over 325 mesh.

18. The F.P.A. is a minimum of 2400°F up to a high of 2700°F.

19. The %O_2 is: -- 1%.

20. The carbon burnout is 99%.

21. There is no slagging on side walls, superheater or convection tubes.

22. Turndown capability is 3:1.

23. The % ash in the coal is 3%.

24. Much of the ash is fine, enough (16-18 microns said Mr. Higgins) to flow through the burner and be trapped in the precipitator at an efficiency of 98%.

25. The ash on tube surfaces is dust-like and easily removed.

26. Further general data of note are:

27. There was a history of short I.D. fan capacity.

27.1 By holding O_2 down to 1%, reducing gas re-circulation and reblading the I.D. fan, they have been able to achieve 125 MW. from the COM fired unit or over 104% of the 120 MW MCR design.

28. On the question of the use of a ceramic as an insert material, Mr. Higgins said that he feared the possibility of fracture from thermal shock.

28.1 I mentioned the ceramic development of our Canadian N.R.C. and said that I would see if N.R.C. could send them information of mutual benefit.

29. The insert technique developed by the Dudley-Higgins team is possibly patentable and so I said that I would send them a copy of the DSS letter of confidentiality.

30. The initial Peabody Bullet Atomizer was selected because of its simplicity of design.

31. The original burner arrangement was 4 rows of 4 burners for a total of 16 changed to burners which were a 4-2-2-4 row configuration.

31.1 F.D. fan press. capacity of 8" WC allowed for tight flame control with the variable vane main combustion air control registers.

31.2 In addition, centre-fired air was applied and controlled by a manually set damper.

32. Cold start up of any unit (COM or #6 fired) is with light oil guns placed in the bottom row.

33. The COM atomizers can burn #6 oil.

34. The viscosity of the #6 oil is targeted for 80 SSU, with an operating range of 100-200 SSU.

34.1 The #6 oil preheat temp. is 250°-270°F based on a #6 having a viscosity of 200 SSF @ 122°F.

35. Generally it has been found that operation with 50/50 COM is the same as with straight #6.

36. Furnace dimensions are 33' wide x 22' long, with flame dimensions controlled to give 4' clearance from outboard burners to side wall and "licking" the rear wall.

36.1 Flame dimensions for a given register vane setting can be controlled by adjusting the atomizing steam/fuel ratio

ARCO Petroleum Products Co.
Harvey, Illinois

19-10-82

Meeting with Mr. Frank Chloupek
Manager Venture Planning and Business Development - and a Group of his staff working on CWM Development

1. The purpose of this meeting was to uncover the progress in CWM made by the ARCO group.

2. ARCO's work on production of CWM has covered the coal concentrations (bone dry) of 50%, 70%, 80%.

3. ARCO do not believe that 70/30 is the ultimate commercial limit of coal concentration in a CWM. They believe that they can obtain, through their research, adequate dispersal and stability of an 80/20 mix.

4. Their efforts cover the coal from at least four of ARCO's mines for which they will send me proximate and ultimate analyses.

5. ARCO are not stressing coal beneficiation by a grinding process, with attrition or other means to an end size of 325 mesh, plus spherical agglomeration.

5.1 They are concentrating on a grind of 80% through 200 mesh and believe their techniques will produce a commercial product.

6. They agree with the theory of Dr. Funk of Alfred University, N.J., that ionic repulsion is a natural phenomenon with finely pulverized coal.

7. It will be interesting to compare their parent coals with the characteristics of coal for which an agglomeration process at 325 mesh size is necessary to obtain sufficient benefication in ash and

.../2

sulphur pyrites reduction.

8. ARCO agree that the coal crystalline structure and the physical characteristics of the ash, as well as its composition, are large factors in the abrasiveness of a CWM.

8.1 They believe that the abrasiveness of a given grind and composition of a CWM can be decreased through chemical additive (s).

8.2 They also consider that the dispersal effect due to ionic repulsion can be increased by chemical additive(s).

9. They are not now cooperating with burner manufacturers to enhance their efforts to produce a commercial CWM.

10. Their first objective is a "normalized"product being:

.1 a mix of the coals from several of their mines.

.2 a CWM from a mine that could provide favorable coal characteristics and have sufficient rate of production and proven reserve tonnage to be commercially viable for the CWM market.

11. ARCO do not seem to look favorably on Carbogel and my impression of the reason is the high cost of processing.

12. ARCO considers that the use of a grind of 80% through 200 mesh can be made into a true CWM (i.e.: a liquid coal fuel).

13. When they have developed a CWM product to their satisfaction, which they consider will require about five years time, they will then cooperate with burner manufactors to develop a successful CWM burner.

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14. One of the engineers on Mr. Chloupek's staff, who was present at our meeting, stated that he had no confidence in the viscosity data given by a Brookfield viscosimeter because it could not operate at speeds that would give shear rates of an order that would be encountered in pipe flow in the field.

14.1 He also considered that ΔP data in a given test loop could not be used as a standard value for pressure drop calculations because viscosity was not a linear function. It was affected by; the particular CWM grind, composition and flow characteristic; fuel velocity and pipe diameter; parent coal.

14.2 Hence, these variables would cause the need of a separate pressure drop calculation for each field situation.

15. Dr. John P. Dooher of Adelphi University is working on this to determine the basic physics of viscosity values so as to obtain a "universal" equation embodying all factors.

15.1 At this date he has developed a semi-empirical equation.

15.2 Dr. Dooher's work is being funded by D.O.E. and a group of the "Empire" states.

16. ARCO have no CWM burning experience, at this date.

17. Their work on COM used coal concentrations of 30%, 40%, and 50% in a #6 oil carrier.

17.1 The "standard" flow temperature in the supply facilities to the burner was 170°F.

17.2 Information on actual burning temperatures of the COM was not known to them (or possibly was information withheld from me).

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18. Viscosimeters considered suitable for CLM work bore names of Fann and Haake based on their capability of providing "precision" viscosity values (presumably their ability to operate at shear rates comparable to field practice.)

19. Mr. Chloupek said he would send me rheograms of their CWM products (in addition to coal analyses) but that he would not necessarily inform me on the relationship of the rheograms and their parent coals.

Forney Engineering Co.
Addison, Texas

Date Seen: 18-10-82

Meeting with Messrs. Norman Buckland
Supervisor, Burner Engineering Dept.
Robert E. Hickman
Manager Combustion Department
James O. Toutz

1. Forney Engineering have developed numerous types of burners and ignitors including the Forney Verloop air atomizing burner.

2. The present CWM atomizer design is shown schematically in Fig. 12 (the actual version - as opposed to the Fig. 1 version derived by me from verbal description by Ken Olen of F.P.L.C.). (See Sect.16, Addendum 3).

3. Forney are developing a modification in which the interacting angles of fuel and atom. air will generate a resultant angle estimated to have less abrasive impact.

4. Both designs will be provided for the Chatham test.

5. Forney use a high swirl value in the combustion air flow, provided by:

.1 Volume control and diffuser for primary air.
.2 Volume control and tangential velocity control by slide damper and positionable vanes.
.3 The general arrangement is shown in Report Fig. 11 which is Foster Wheeler Limited dwg. "Fig. 2.9 - CWF Burner."
.4 The wind box pressure is of the order of 4" W.C.

6. I observed a demonstration of CWM burning in Forney's test furnace which is 8' I.D. x 27' long with the 1st 12' lined with 4" refractory.

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7. The furnace is water jacketted, open vented, operating at 212°F.

8. The CWM was provided by Gulf and Western with the mother coal a West Virginia bituminous having 26% V.M.

8.1 The CWM was based on a 200 mesh grind with benification of:

.1 Ash ----------------------------------12% - 2½%
.2 Sulphur ------------------------------1½%

9. The firing rate during the test was 40.10^6 Btu/Hr. and the procedure I observed was as follows:

.1 The natural gas ignitors rated at approx. 4.10^6 Btu/Hr. were started.

.2 After a period to warm the Quarl & refractory lining, the CWM was turned on, with the ignitors kept on, and the combustion air temperature was built up to a value of 400°F - within a few minutes.

.3 When the furnace reached 212°F the ignitor was turned off.

.4 During this whole process the combustion process was completely stable, with no pulsation.

.5 The fluid pressures were:

CWM -------------------------------------70 PSI
Atom. Air -------------------------------70 PSI

.6 I observed the flame, with the combustion air at 400°F, for approximately 7 - 10 mins. It maintained itself fully stable, with no side tails or sparklers, and sized approx. 3'6" - 4'0" dia. by approx. 12' long.

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.7 There was evidence that the flame had a high tangential velocity component.

.8 At some point in time, with the combustion air at 400°F, I observed a "ringing" of the furnace, at a point about 10 ft downstream. This ringing is presumably throw-off of semi-molten ash by the centrifugal force of the tangential component of flame velocity.

.9 This phenomenon may be peculiar to the operating conditions of a single high capacity burner in a cylindrical furnace at high swirl number.

.10 Forney are quite aware of this and are undertaking suitable R & D including reduction of tangential velocity and increase of axial velocity.

.11 It is believed that this phenomenon will not occur in the Foster Wheeler SA boiler at Chatham, because of the different furnace geometry and the inter-effect of multiple burners (which, presumably, could permit a decrease in tangential velocity without decrease in flame stability.

10. Given a flame dimension of say 4' x 10' the unit heat release would be:

$$\frac{40.10^6}{\pi r^2 \ell} = \frac{40.10^6}{\pi \times 2^2 \times 12} = 265,250 \text{ Btu/ft}^3\text{/Hr.}$$

within the flame envelope.

11. At test end the combustion air temperature was reduced from 400°F to ambient, other conditions remaining unchanged. The only difference I observed was an increase of approx. 10"-12" in the distance from burner to flame front.

12. The demonstration described was also witnessed by Messrs. Neil R. Raskin, and Thomas K. Hammond of the Foster Wheeler Energy Corporation.

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13. Forney advised % O_2 as low as 1½% but had no quantitative data in % burn-out at this low excess air value.

13.1 They consider "normal" operation would be at 3% O_2.

14. Forney will be continuing R & D on atomizer design, and will assess the possibility of using steam as the atomizing fluid. For the latter purpose they have a boiler rated at 770 PPH, capable of providing up to .175 lb. atom. steam/lb. fuel. (@ 442 USgph)

15. A further R & D effort on atomizer design will be the elimination of the cone distributor.

16. As R & D provides superior equipment these will be provided for trial at Chatham.

17. It should be noted that Forney consider the combination of 212°F furnace water jacket temp., plus the 4" refractory, as having an effect on combustion equivalent to a boiler fluid temp. of approx. 500°F (665 psig. saturated).

Section 20

North American Manufacturing Co.
Cleveland, Ohio

14-10-82	Meeting with Mr. John Ramsdell, Manager of Engineering
10-12-82 13-12-82 15-12-82	Tel. discussions with Mr. Don Moreland, Sales Manager Steam Generating Equipment
17-12-82	Letter from Don Moreland

1. To date (14-10-82) the only North American CLM experience was a short time firing test of a low air pressure burner (similar in design to Hauck LAP) to prove combustion ability (presumably on a COM fuel)

2. Starting in January, 1983, North American will undertake R & D on firing a 50/50 COM, with the following three types of their (many) atomizers:

a) Bulletin 56.42 -
1. Full emulsion atomizer (internal atom.)
2. 500 US gph per sq. in orifice area.
3. .48 lb. atom. steam/lb. #6 oil @ 80 psi.
4. Single or multi-part atomizer.

50/50 COM with N.A.
Burner No. 6795 -
Short Test

b) Bulletin 56.43 -
1. Tip emulsion atomizer "Delavan" type
2. 1200 US gph per sq. in. orifice area.
3. .17 to .20 lb atom. steam/lb. #6 oil.
4. Single or multi-part atomizer.

40/60 COM with N.A.
Burner No. 6795 -
Short Test -
No Measureable Wear

c) Bulletin 56.22 -
1. External atomization
2. ½" dia. oil tube for 250 USgph.
3. .24 lb. atom steam/lb. oil
.37 lb. air/lb. oil
4. Single part atomizer.

3. All of the above atomizer data is entered in Table 1A.

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4. North American consider that it should be possible to use the above atomizer designs with variable vane type circular registers provided the combustion air flow patterns can be made compatible with the North American atomizer "heat patterns" (fuel spray pattern range -?).

5. N.B. (a) In Bulletin 56.42 it is stated that "5642 atomizers can be adapted to fit most burners but they should not be used for 'low temperature furnaces' or installations where'cold lightings are frequent'".

(b) In Bulletin 5654-1 it is stated that "Seried 5643 Atomizers permit quicker, clean lightups in 'cold settings' when used in appropriate burners such as "North American Series 6820 or Series 6795' ".

(c) In Bulletin 56.22/56.23 it is stated that "Series 5622 & 5623 Nozzle Mixing Atomizers produce 30° spray angles and fairly long flames such as required for steel mill reheat furnaces, rotary dryers and other 'long combustion chambers' ".

6. North American also have an LAP type oil and oil/gas burner,comparable to Hauck, with atomizing air pressure range of 14-24 osi: oil pressure at inlet of 25-30 psi,and a capacity range of $.8.10^6$ to 7.10^6 Btu/Hr.

7. North American have burned oil field viscous crudes containing gritty material, with their 56.43 atomizer in tungsten carbide alloy.

8. For special process work North American have special designs including:

a) Refractory lined burners for combustion air temperatures up to 1100°F (N.A. bulletin 68.19).

b) Self recuperative burners utilizing hot flue gas to preheat combustion air (N.A. Brochure 5-R-B).

NORTH AMERICAN MFG. CO.
4455 EAST 71ST STREET CLEVELAND OH 44105 USA

December 17, 1982

Mr. Ralph Grossman
650 North Atlantic Avenue
Beachwinds - Condo Unit 106
Cocoa Beach, Florida 32931

Dear Mr. Grossman:

As per our telephone conversations of December 13th and 14th, I am enclosing two (2) copies of Bulletin 56.22/56.23 describing external mixing, high pressure atomizers. In general, these atomizers do not provide as fine a degree of atomization as do the 56.42 and 56.43 atomizers which you discussed with John Ramsdell and Jim Watson at the time of your visit. However, we often use the external mixing type with difficult liquids containing solid particles because the straight thru design of the oil tubes and nozzles provides minimum pressure drop and opportunity for obstruction. The capacity tables are based on a specific steam consumption of 2.0 lbs.per gallon of fuel oil. (.24

Regarding the 56.43 tip emulsion type atomizers, mixing nozzles are nominally rated at 1200 gallons per hour per square inch of nozzle area. This compares to 500 gallons per hour per square inch of nozzle area for the 56.42 full emulsion type atomizers.

The higher specific steam consumption of the 56.42 atomizers as compared to the 56.43 atomizers is inherent in the design. It does not imply that the former will handle oil of higher viscosity than will the latter. We have records of applications where both the 56.42 full emulsion atomizers and the 56.43 tip emulsion atomizers have successfully performed with oil at a viscosity of 150 SSU.

To aid in your cost studies, I have priced 4 ft. long atomizers of the three types which we have discussed. The 56.22-1B external mixing atomizer has a current list price of $585.00. The 56.42-1-200 full emulsion type atomizer is priced at $495.00. The tip emulsion type 56.43-1 atomizer is priced at $1,265.00 with an addition of $300.00 for tungsten carbide inserts in the critical wear areas. I hope that this information will enable you to complete your study for the Department of Energy, Mines & Resources.

Best wishes for the holiday season.

Sincerely,
NORTH AMERICAN MFG. COMPANY

Don Moreland

Don Moreland, Sales Manager
Steam Generating Equipment

DM:ek
CC: Messrs:
John Ramsdell
Jim Watson

Enclosure: (2) Bull.56.22/56.23

National Research Council
Ottawa, Ontario

Date: Sept. 29, 1982

Re: Flo-Sonics Atomizer

Meeting with: Dr. Ed Capes
Mr. William Thayer
Mr. Kevin Jonasson and
Telephone discussion with:
Dr. Capes, 4-10-82

1. N.R.C. have developed a Flo-Sonics atomizer with:
   - a) modifications to basic design of the Fluid Kinetics-Flo-Sonics atomizer.
   - b) Ceramic inserts, based on a proprietary formula, that can be accurately machined and is not subject to cracking or spalling due to thermal shock.
   - c) A basic ingredient is aluminum oxide.

2. The modifications were developed to provide combustion stability and flame control with CWM, and long atomizer life.

3. Proof of thermal stress capability was established by tests in which the ceramic section was heated to a temperature of 1200°C (2192°F) and subjected to a high intensity blast of cold air, simulating the effect of many hundreds of hours of actual operation.

4. A combustion test to prove COW burning capability of the Flo-Sonics atomizer was carried out in a test furnace 1 metre diameter by 4 meters long. With adequate air supply and adequate swirl,a furnace of this size should be capable of handling an input of 20 x 10^6 Btu/Hr.

5. However, due to the design of the first experimental combustion air register with fixed vanes, the available combustion air flow limited the firing rate to .8 USgpm (6 x 10^6 Btu/Hr) with a lazy orange flame.

6. The vanes were modified and a satisfactory partially transparent white flame was produced.

6.1 The CLM fuel was a COW mix of 55% dry basis coal, beneficiated by the NRC spherical agglomeration procedure, 15% water and 30% #6 oil. The coal was a high volatile bituminous from the Cape Breton Development Corp. and the ash content of the beneficiated coal was 1.5% (Sèe Atlantic Research Laboratory Technical Report No. 33, NRCC 11916).

7. Following the combustion capability test, a 200 hour abrasion resistance test,using the 55:15:25 COW mix,of the Flo-Sonics nozzle with the NRC developed ceramic inserts was conducted in a hot spray test loop.

8. The wear results are shown in the NRC graph entitled "% Increase in CdA_o[(1)] vs. lbs. Solids Discharged" for which see Appendix No. 4.

9. The flow conditions were:

Av. flow rate ---------------------------------1.35 USgpm
Atomizing air pressure ---------------------- 100 psi (producing sonic velocity)
COW pressure -------------------------------- 115 psi
COW temperature --------------------------- 135°F

10. Appendix 4 is a calculation aimed at determining a value for % increase in CdA(1) at 1000 hour flow time as compared to the 5.25% shown on the NRC chart at test terminal time of 200 hours.

11. The essential data brought out in Appendix 4 are:

.1 A 45% decrease in % CdA increase rate after a 53 hour flow time.

.2 Extropolation of the slope of the curve from the 53 hour point through the final 200 hour point to a hypothecated 1000 hour point shows an increase in the % CdA rate to a value of over 21%.

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(1) CdA is a composite number including the flow coefficient Cd and the orifice area A.

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12. If the curve extension at the given slope is real, then it is probable that atomizer rejection before 1000 hours might prove necessary.

13. It is suggested that a minimum test time of, say, 500 hours is essential to prove real combustion operating life of the NRC Flo-Sonics nozzle.

14. In the forthcoming combustion test of the atomizer, it will be provided with a suitably designed combustion air register, in which the primary air (to the diffuser) and the secondary air flows can be variably controlled, including the swirl factor.

15. Appendix 5 covers fuel, atomizing air and emulsion velocities from orifice data for air and fuel, kindly provided by Mr. Kevin Jonasson and from oil port dimensions provided by Dr. Ed Capes.

Combustion Engineering Superheater
Canada Ltd.
Ottawa, Ontario

Date: Sept. 27, 1982

Meeting With: Mr. David Winship - V.P. & Chief Engineer
Mr. G. J.Sailer - Director of Engineering
Mr. J.D.Kearns - Supervisor, Design Performance Engineering

1. This meeting was primarily a P.R. event - little engineering information was obtained.

2. Actually, it is my opinion that C.E. Canada were not too sure of the detailed design charactistics of the CLM atomizer to be provided by the parent company in Windsor, Connecticutt, who have been developing the atomizer under subsidy from EPRI.

3. The few hard facts I was able to obtain were:

.1 The C.E. Red Liquor Atomizer, which is the likely basis of their CLM design, is a modified version of their standard "Y" jet and is called the "J" Tip.

.2 The basic modification appears to be that the fuel flow is unidirectional with the atomizing fluid (steam or air at 125 psi pressure) impacting the fuel at a point just behind the exit orifice.

.3 The differential pressure between atomizing fluid and fuel is plus 15 psi, with the emulsion output at sonic velocity.

.4 The max. capacity of the atomizer was given as 2500 kW. If kW is thermal the capacity in Btu is approx. 9.10^6 Btu/Hr = 60 USgph #6 oil.

If the kW rating is electric then the capacity in Btu's is approx. 30.10^6 Btu/Hr = 180 US gph #6 oil.

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.4.1 The capacity data per CLM atomizer will be checked, and real min. and max. capacity values for the CLM atomizer in USgph of CWM or COM obtained.

5. It is my "hunch" that several atomizer designs would have been developed at Windsor and more than one design to be tried at the Chatham Test on the 40 Meg. boiler (C.E. corner firing).

4. With EPRI approval and from C.E.'s work at Chatham, N.B., I am confident that I shall obtain from C.E., Windsor, Conn., data on the results of their R & D that can be entered into Table 1 and 2 to establish comparisons and aid in determining the optimum CLM atomizer design.

Combustion Equipment Associates Ltd.
Boisbriand, Québec

DATE: Oct. 29, 1982

Meeting with: Mr. Francois Grimard, President
CEA (U.S.A.) Canadian Operation

L. The work on atomizer development for COM is being done by CEA (USA) Subsidiary Combustion Technology International, whose address is:

East Street,
Portchester, Hampshire
England PO169RD

2. The R & D is being done under contract to British Petroleum (Contact is Mr. Colin Bell) who have developed a COM fuel with "good coal oil dispersion and no tank settlement.

3. Because of this relationship, no work is being done, or now contemplated, on CWM.

4. The R & D on a COM atomizer is directed to abrasion resistance, and their efforts on design and materials is still experimental.

5. The basic atomizer being developed for COM work is the "Skew" atomizer originally developed by the ABC Co.of Portsmouth,England, who were taken over by CEA (USA).

6. My memory from an examination of this atomizer, a number of years ago,is it has a complex design of internal atomization with many fine "Skew"convolutions and orifices, designed primarily for minimum possible atomizing steam consumption, consistent with fine atomization.

7. Mr. Grimard essentially confirmed this by his statement that research was addressed to adopting the oil design channels and orifices for COM work.

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8. I shall discuss with Mr. Whaley the question of furthering work on this atomizer by telephone contact with Combustion Technology International and with British Petroleum.

9. CEA (USA) (New York, and Bridgeport County), have developed a combustor to burn refuse fuel pellets. (See Bulletin No.11) I shall also discuss this with Mr.Whaley.

F. J. Raskin Inc.
C/O S. D. Combustion Specialists (1976) Ltd.
6650 P. E. Lamarche, Montréal

Preliminary Report 17-11-82

1. The Raskin Co., was taken over by S. D.Combustion Specialists (1976) Ltd. of Montreal.

2. John Raskin kept an office in the S. D. Combustion offices and, to my understanding only worked as a salesman.

3. About two months ago, I was informed, on good authority, that John Raskin was no longer associated with S. D. Combustion.

4. The original Raskin Co. handled the Raskin Steam atomizer register burner, and were agents for the Coen air atomizing burner.

5. The Raskin steam atomizing burner was very similar to most internal mixing steam atomizing designs such as Peabody,Faber, National Airoil and Todd.

6. When S. D. Combustion used the Coen burner, I understand, that they "worked it over" and modified it somewhat in accordance with their concept of burner design.

7. I understand, from contacts made in the period 1978 - 1980, that S. D. Combustion were (and probably still are) agents for the Gordon Piatt air atomizing burner which they used without (known) modifications. I believe that Gordon Piatt were then a subsidiary of Peabody.

8. The data on Gordon Piatt will be found in my report to E.M.R. entitled "A Program to Conserve Oil and Gas in Canada by Improved Combustion Efficiency" May 1982.

9. The data on the Gordon Piatt were obtained and recorded strictly with reference to oil and gas burning.

9.1 The design data then obtained on the Gordon Piatt (Item 8) does not identify any particular features of suitability for its use with a CLM fuel.

10. For low pressure air atomizing burners, suitable for CLM use, I believe that it would be desirable to investigate Coen in San Francisco and Verloop care of Forney Engineering (or Foster Wheeler Corp), in addition to the Hauck burners reported on in Section 2 of this report with technical details given in Section 2 of Tables 1 and 2.

Section 25

Ontario Research Foundation
Sheridan Park, Mississauga, Ont.

Date: Nov. 13, 1982

Meeting with: Mr. Lou Bruno, Manager Engineering and Combustion Systems, Department of Metallurgy

1. In the ORF testwork on the Gulf Vortometric burner1), no major changes were made to the burner, which was provided in general accordance with ORF specs., except only those modifications requested by Gulf to provide improved combustion. These changes included:

.1 Changing the swirl vanes to an adjustable type to provide a "diffuser function" (flame holding?) and to increase the range of the swirl number of the main combustion air stream.

.2 Increasing the tolerance band, i.e. providing a greater span, for air/fuel ratio adjustments.

.3 Varying the fuel exit orifices with respect to the atomizer longitudinal axis and the atomizing steam flow pattern.

.4 Changing the divergence angle of the atomizer outlet (See Fig. 18) from that of the original Vortometric design.

2. Lou Bruno stated that the high tangential velocity of the atomizing steam flow, in the Vortometric design, protected the atomizer discharge nozzle from the impact of the CLM fuel.

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1) "Coal Oil Slurry Combustion & Tribology - A Canadian Experience" by L. Bruno, D.S. Dehpand and Horace Whaley. Proceedings of the Fourth International Symposium on Coal Slurry Combustion, Orlando, Florida, May 10-12, 1982.

Conamara Ltd.
Oakville, Ontario
Trademark "AECO" (Anderson Co.)

Date: Nov. 13, 1982

Meeting with: Mr. Lou Anderson, General Manager
Mr. Shad Williams, Director, R & D
Mr. Harry Kondratas,General Eng. Dept.

1. The atomizer currently being manufactured by Conamara is essentially the basic design of the Gulf Vortometric burner shown in Fig. 4 in the paper by Bruno, Deshpand & Whaley (1) plus the improvements by ORF as noted in my report on ORF i.e. changes to

   a) orifice angle
   b) divergent nozzle angle
   c) variable type combustion air vanes.

2. The refractory combustor design may also be changed as R & D may indicate for optimum air/fuel ratio control. See Fig. 19 .

3. The correct name designation for Vortometric is now "AECO" (e.g. Aecometric Burner).

4. Conamara are currently conducting two tests, one on COM and one on CWM; using their basic atomizer design (i.e. formerly Vortometric - improved by ORF) but with some change possible in the "toroidal" combustion chamber design for application to COM or CWM burning.

5. Some mixing of atomizing steam and fuel does take place in the divergent section of the nozzle but as ORF have stated, the high tangential velocity of the atomizing steam serves as a buffer against the impact of coal particles.

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(1) "Coal Oil Slurry Combustion and Tribology - A Canadian Experience" by Loy Bruno, A. S.Deshpand and Horace Whaley. in the Proceedings of the Fourth International Symposium on Coal Slurry Combustion, Orlando,Fla.,May 10-18,1982.

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6. In the technical data, to be shown in Tables 1B and 2B , it will be seen that the turn down rates are 8-10:1 at an atomizing pressure of 35 - 75 psi for air or steam and 20:1 with low pressure of 3-5 psi. The reason for this T.D. variation is:

.1 When high atomizing pressure is used the pressure is varied in accordance with firing rate maintaining an approx. constant ratio of pounds atom. fluid/pound fuel.

.2 With low atomizing pressure (air) the pressure remains constant when the oil pressure is reduced, so that the ratio of lbs. atom. fluid/lb. fuel increases as firing rate decreases.

7. For low turndown range, the toroidal chamber design must provide a highly turbulent diffusion flame (many small eddies with diffusion flame mechanism in each eddy - as reported).

8. Conamara stated that their present trials with variable control vanes is experimental - they may go back to fixed vanes.

9. A COM demonstration will be made at Georgia Pacific, in January 1983.

10. Please see Figures 17 and 19 re:

1. General arrangement Dwg. of an AECO Kiln Burner with air assist atomization (and presumably, high oil pressure).

2. General Arrangement Dwg. of a Standard (presumably) industrial AECO Burner.

.2.1 Conamara believe that this kiln burner type may have merit with COM or CWM firing.

.../3

11.	A new possibly radical design of CWM burner is being developed and should be ready for testing (or have already been tested) by June 1983.
12.	See Table 1B,Sect. 12 and note respective velocities and abrasion index velocity number for flow through fuel orifices and through divergent nozzle. Reference data columns are nos. 10, 11, 12, 13. 14, 16 and 17. See also Appendix 7 for the relevant data and calculations, on flows and velocities.

Fluid Kinetics Inc.
Fairfield, Ohio

Date Seen: October 15, 1982

Meeting with: Mr. Paul Koppahele
President

1. Paul Koppahele's description of the Fluid Kinetics atomizer closely identified with the exploded view of the atomizer as shown in the drawing provided to me by N.R.C. (see report on N.R.C. meeting Sect.21).

2. The original atomizer design upon which Fluid Kinetics developed their unit was that made by Decafix Ltd., Lincolnshire, England.

3. A test program on CWM firing with the Fluid Kinetics atomizer is being undertaken by the Brigham Young University, of Salt Lake City, together with the USA lab in Los Alamos.

4. The max. capacity of the Fluid Kinetics atomizer, for general purposes, is 14,000 USgph.

5. Fluid Kinetics have tried to use ceramics, in the construction of their atomizer but experienced difficulty in machining the ceramic pieces (I told Paul Koppahele of the N.R.C. experience with ceramics).

6. Atomized fuel stream pattern is controlled by the design of the end of the deflector part i.e. by diminishing or increasing the diameter of the exit end of the spray deflector.

7. The Flo Sonics atomizer can be modified for the injection, and atomization, of several streams of fluid into the atomizing air stream as shown in Fig. 20.

8. Paul Koppahele is essentially an inventor and developer and not an applicator. Dimensional data of the Flo-Sonics, from which fuel velocities can be determined, must, it seems, be obtained from N.R.C. or Ken Burrell of Scotia Liquoal or both.(Information was obtained from N.R.C., see Report No. 21.)

.../2

8.1 Paul did say the fuel velocity need be just sufficient to allow the CWM to be picked up by the atomizing air stream.

9. A point of interest made by Paul was that the Flo-Sonics had successfully atomized "aluminized wax" at a viscosity of 1200 centipoise (approx. 5500 SSU).

10. Paul also gave me the sheet attached, (Bulletin No.9) which shows the relative wear and costs of various wear resistant materials. (This is either a commercial by the "Astro Met Associates Inc." or is actual data based on engineering. tests.

11. In the Fluid Kinetics Bulletins attached, on their Flosonic atomizers, atomizing air versus fluid (CWM ?) flow rates are given in the table on Page 3. (The equivalent atom. steam rate is given as 2.4 x the air rate).

11.1 With the Model DX-2 atomizer, rated 516 USgph the ratios of weight of atom. fluid per lb. of oil (assumed #6) are:

$$\text{air} - \frac{18 \times .076 \times 60}{516 \times 8.33} = \frac{82}{4300} = .02 \text{ lb/lb water}$$

$$\text{steam} - .02 \times 2.4 = .05 \text{ lb/lb fuel}$$

N.B.: These values (presumably) are for atomization of water. The values are approx. 1/3 of the values found for atom. of #6 oil or CWM as shown in Table 1 of this Report.

12. The actual atomizing flow requirements for CWM must be determined (from N.R.C. or Scotia Liquicoal or by test). (N.B. NRC tested at 25 SCFM for 2.3 USgpm).

W.N. Best Combustion Equipment Co.
Division of Preferred Utilities
Danbury, Conn., U.S.A.

Date: 28-7-83

Meeting with: Mr. John Akin, General Manager, W.N. Best Equipment
Mr Richard Stone, President Preferred Utilities
Mr. David R. Perkins, Vice President - Sales, Preferred Utilities

1. The meeting time was chiefly with Mr. John Akin, General Manager of W.N. Best because of a long-ago memory of the "Lip" (actually shallow trough) design of the Best Burner.

2. It was essentially a flat flame burner, but my hunch was confirmed in that the "lips" could be shaped to a curve which in conjuction with a suitable combustion air register and a suitably directed atomizing fluid, could produce a variety of flame shapes (see FIG. 26) for the general design of the W.N. Best atomizer.

3. Because of the Best "lip" design and the Urquhart Vortex cup have similarities in function, I used the technique of my analysis of the Urquhart atomizer to find an erosion velocity index number of $<$ 3 fps, on the lowest of the 28 recorded in the tables, and comparable to the North American single hole full emulsion burner model 56.42 (see item 20[a] page 3A of Table 1a for North American and item 27 page 3B of Table 3).

4. In my opinion the major erosion would occur on the "lip" surface and it would seem readily adaptable to the use of a high alloy or a ceramic insert.

5. Since merging with Preferred Utilities, W.N. Best have been involved in developing high capacity rotary burners, from Preferred's maximum of 120 USgph to Best's (rotary) maximum of 60,000 lbs./hr.

6. Figures 26.1 and 26.2 show respectively a "lip" design, jacketed for high temperature application, and a rotary design rated 50,000 lbs. on spent acid.

7. I am adding the C.E. Canada, and the W.N. Best data to evaluation tables B & B.1 and will adjust the resulting ranking of the burner group accordingly.

8. I should note that the relatively small flame dimensions for Best burners at 200 and 600 USgph were definitely confirmed by Mr. John Akin of W.N. Best. (See Sect No. 28, Table 2B, page 1B, column 9.)

C.E. CANADA
99 Bank St. - Ottawa, Ont.

Date: Sept. 7, 1983

Re: C.E. Canada Y "Type" atomixer for Chatham N.B. demonstration on a 22.5 Meg. C.F. Combustion Engineering Boiler.

Meeting with: Mr. David Winship, President
Mr. David Cook, Performance Design Engineer.

1. This meeting was arranged by invitation from Mr. David Winship, following my conversation and letter of June 29 to Mr. D.A. Smith, Supervisor Combustion Component Research of C.E. Power Systems, division of C.E. Inc., Windsor, Conn., U.S.A.

2. It was my understanding that Mr. Winship had been requested to give me the maximum possible of the data of my technical questionnaire.

3. As a return gesture of good will I brought with me atomizer sketches of units for which I had been given written and verbal permission for disclosure by a group of manufacturers, save only data on certain dimensions.

4. The group and their answers were:
   a) Process Combustion Corporation
   Mr. Peter B. Nutcher, V.P. and General Manager.
   No limit to disclosure, including OK to submit copy of my Appendix No. 1, in which I attempted to analyse the performance of the Urquhart Vortex cup atomizer.
   b) Hauck Manufacturing Co.
   Mr. John A. Marino, Sales and Engineering
   Permission to disclose atomizer design except only mfg. dimension data (which were "whited out" from the sketches for presentation to C.E.
   c) Conamara Limited
   (Successors to Gulf-Vortometric)
   Mr. L.E. Anderson, General Manager
   Permission to disclose atomizer design except only dimensional data as in Case b) above.
   Copies of these letters are attached to this report.
   In addition to the above I was able to submit further atomizer data as follows:
   d) Florida Light & Power Co.
   Dr. Ken Olen
   Permission to submit design sketches on ICL burner (as modified by FLPC) but to eliminate all dimensional data - as in Case c) above.

e) Fluid Kinetics Inc. (Flow-Sonics Atomizer)
Mr. Paul Koppahele, President
This atomizer is covered by patent protection, (copy of which is in my possession) and I therefore felt free to disclose, except that dimensional data given me by N.R.C. (Canada) on one of the sketches were "whited out".

f) Atlantic Research Corporation
Dr. E.T. McHale, Tech. Dir.
The ARCO atomizer sketch had been published in the technical literature.

g) Faber Burner Division of Keeler-Dorr-Oliver Corp.
Mr. Wm. Morgan, General Manager
Verbal permission to submit Faber Standard arrangement burner drawing - which contained no actual dimensions.

5. We now proceed to describe the data received from C.E. Canada.

6. The first C.E. atomizer designs considered for the Chatham Demonstration are shown on Figs. 1, 2, and 3 attached to this Report No. 25.

7. From inspection only, it would seem that the "Red Liquor Design" of Fig. 1 would have the least emulsion velocity, and therefore presumable a maximum life for a given metallurgy.

8. Fig. 3, called the "EPRI" nozzle was the design expected to be used at Chatham.

8.1 In this design it will be seen that fuel and atomizing air channels have been "reversed". However, comparing the junction angles of fuel and air in Figs. 2 and 3, it would seem (if the sketches represent reality) that the main design difference, in Fig. 3 design compared to Fig. 2 is a decrease in the angle of impact of the atomizing stream upon the fuel streams.

9. Fig. 25 (in section "Figures") shows the general arrangement of 3 atomizer design sections: (a) the atomizer proper; (b) the use of centre fired annular air stream to longitudinally impact the atomized emulsion issuing from the atomizer ports; (c) the use of a ceramic quarl presumably to (d) assist ignition and/or (e) shape the atomized fuel/steam emulsion flow.

10. Fig. 25 shows the design of the combustion air flow streams through 1) the standard air channel (upper) as used in oil (or also possibly in P.F. flow operations) and (2) the standard coal/air channel

(lower) as used in P.F. firing and now used as an extra combustion air channel in CWM firing.

10.1 The actual "Y Jet" design of the atomizer may be that of Fig. 3 (EPRJ nozzle) or may be some other design variant.

11. Now refer to Appendix No. 10 and note:

Item 10	- emulsion velocity	- 898 fps
Item 12	- "effective velocity"	- 16 fps
Item 14	- erosion index	- 18 fps

11.1 All these values are higher than the velocity of all other atomizers investigated.

12. It could well be of course, that the "overall" atomizer design together with the use of high erosion resistant alloy or ceramic inserts, may give the necessary life of 1000 hours. (See Table C) before need of rejections.

13. Again referring to Appendix 10 note:

Item 15	- shear rate of emulsion through exit ports	190053 ft.sec.^{-1}
	- shear rate of fuel through exit ports	3395 ft.sec.^{-1}

13.1 It could be most interesting, in my opinion, if the following facts could be determined:
a) the viscosities corresponding to the shear rates,
b) the nature of the CWM particles within the air/water/fuel emulsion corresponding to the shear rates,
c) the energy within the exit ports,
d) a quantitative and qualitative energy profiles downstream and of the exit ports,

13.2 From the literature it would seem that the median diameter of the CWM fuel particle should be about 100 uM, if the burning characteristics of #6 fuel oil is desired.

14. Perhaps, presumptuously, I add the following remarks regarding certain basic requirements of burner operations:
a) adequate positive ratio of air/fuel pressure,
b) adequate atomizing air,
c) knowledge of pressures within the four flames and the centre of fireball,

d) the possibility of such pressures in causing reagglomeration of the CWM coal particles,

e) c) & d) would involve knowledge of the swirl numbers involved,

15. Fig. 5 extracted from "Coal-Water" Slurry as an Alternate Fuel" by Rolf K. Manfred, 1) and included in this Report No. 25 shows the relative small effect of temperature of CWM particle size at supply rates below .12 lb air/lb. fuel.

16. Below the value of .12 pounds/lb., the curve (Fig. 5) shows the start of an asymptote. Could operation at an atomizing air ratio of .12 be somewhat hazardous?

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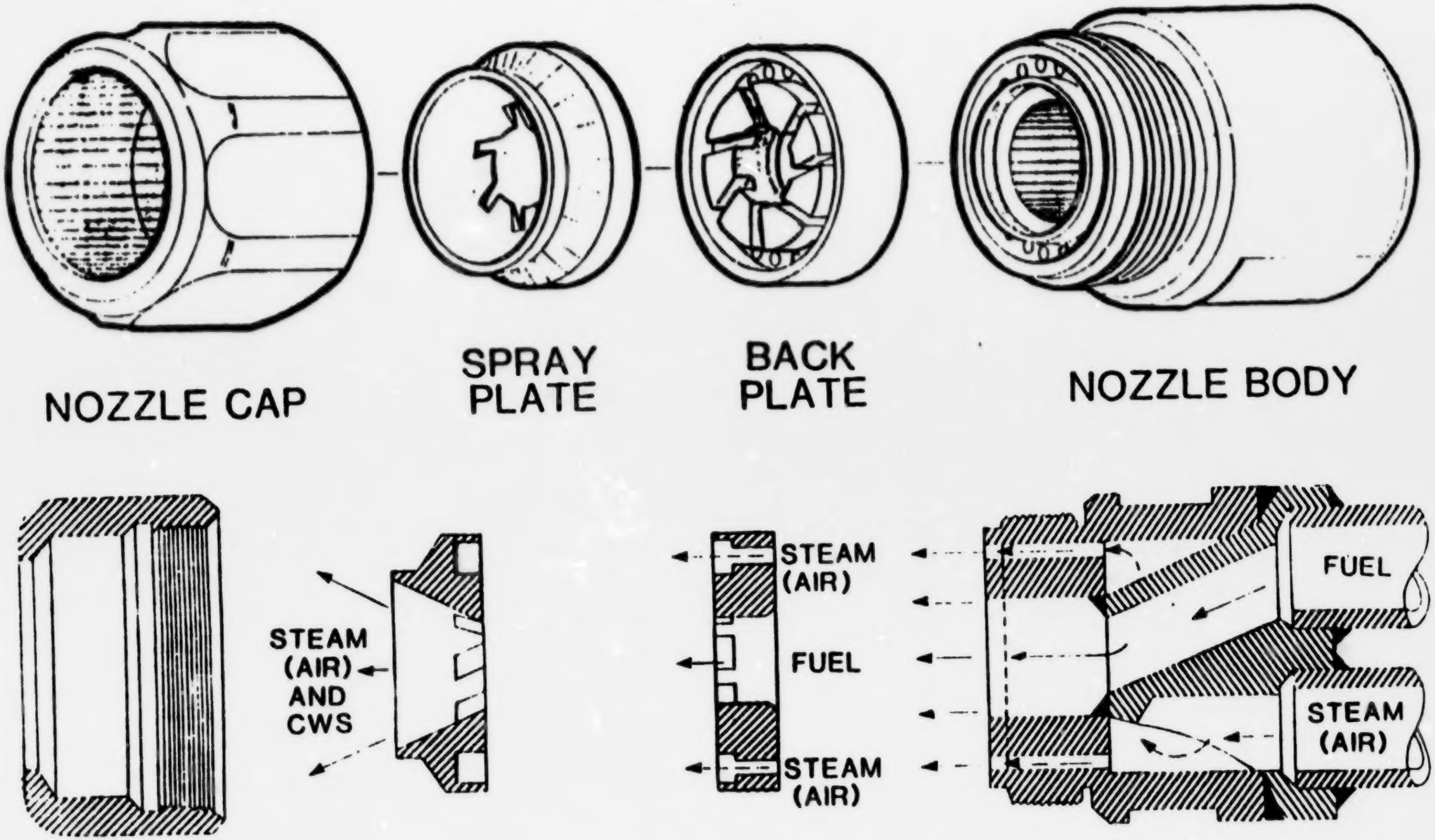
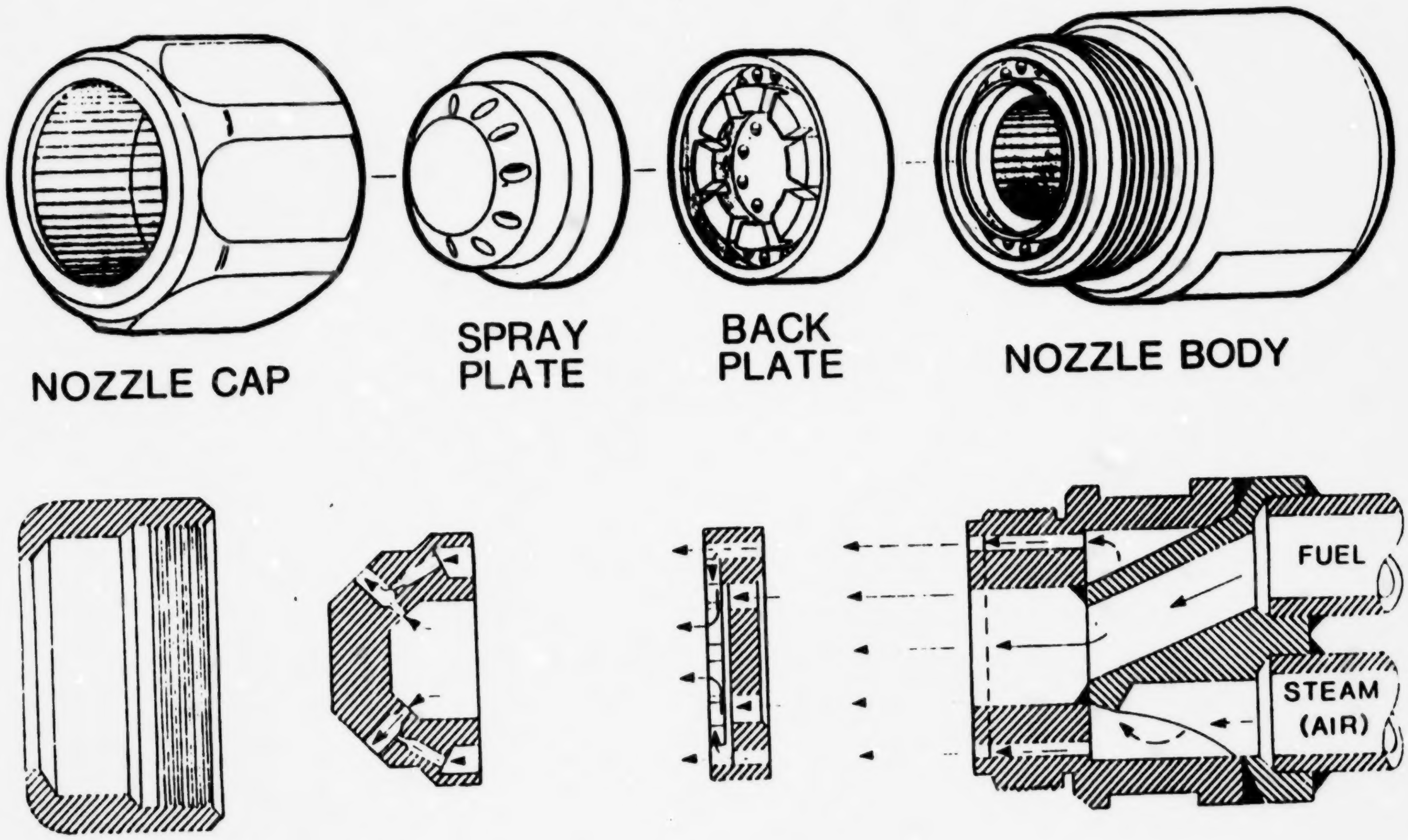
1) Presented at Coal Technology '82, Houston Texas, 9 December, 1982.


NOZZLE CAP
SPRAY PLATE
BACK PLATE
NOZZLE BODY
STEAM (AIR) AND CWS
STEAM (AIR)
FUEL
STEAM (AIR)
FUEL
STEAM (AIR)

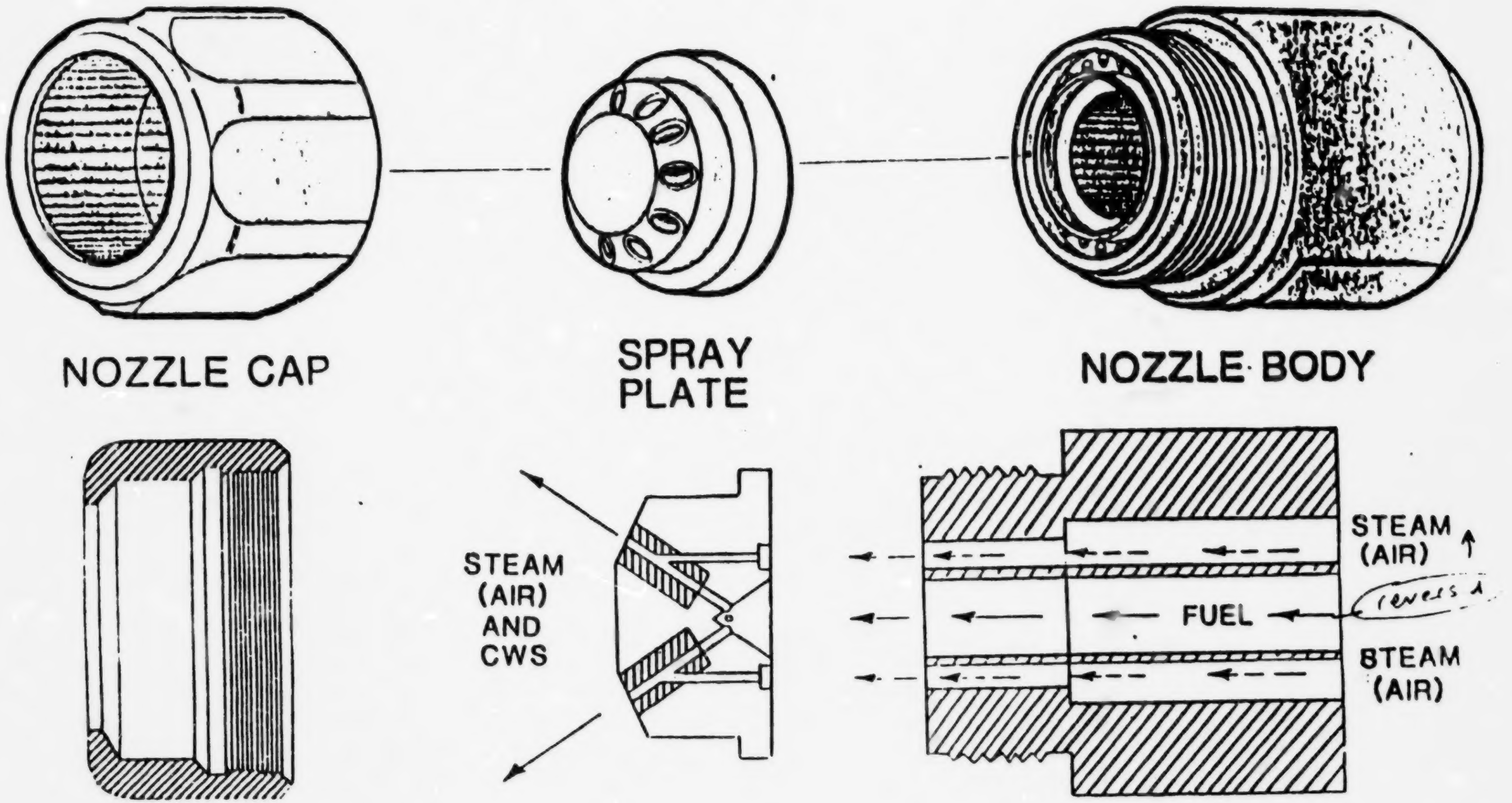
SPRAYING PARTS
FOR
ALTERNATIVE #1

FIG. 1


NOZZLE CAP
SPRAY PLATE
BACK PLATE
NOZZLE BODY
FUEL
STEAM (AIR)

SPRAYING PARTS
FOR
ALTERNATIVE #2

FIG. 2


NOZZLE CAP
SPRAY PLATE
NOZZLE BODY
STEAM (AIR) AND CWS
STEAM (AIR)
reverse λ
FUEL
BTEAM (AIR)

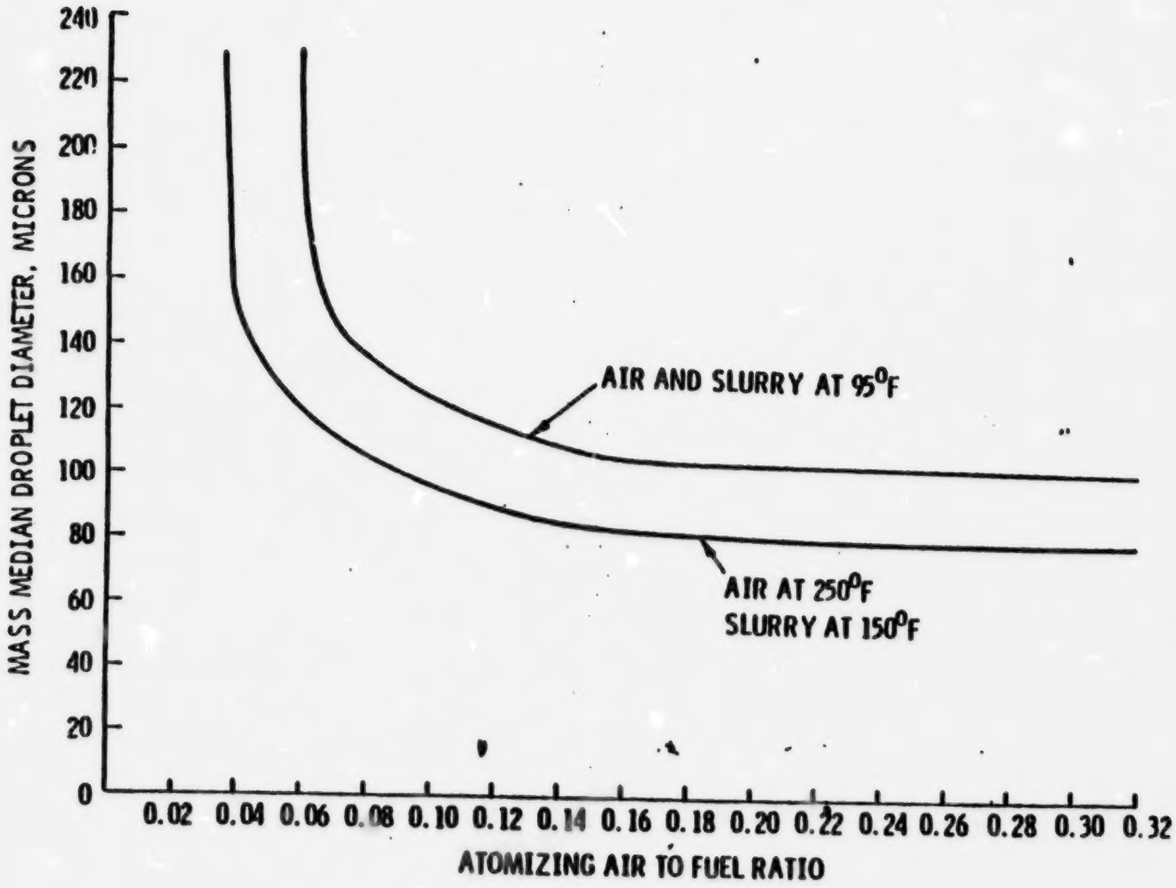
SPRAYING PARTS
FOR
ALTERNATIVE # 3

FIG. 3

EPRI nozzle

Figure 5.

EFFECT OF SLURRY AND AIR TEMPERATURE



Johnston Macco
Division of Schlumberger Technology, Houston Texas
Flopetrol Oil Fired "Mud" Burners

Phone discussion date: 15-7-83 Mr. Gilbert Prongué, Manager of Flopetrol interests outside North America.
4-8-83 Mr. Grady L. Hillman, Assistant to Mr. Prongué

1. The genesis of the interest in Flopetrol was an ad in Oil Week by the Canadian agent Johnston Schlumberger located in Calgary, which referred to the Flopetrol burner as capable of burning "test produced unstabilized crude or crude "mud"-water mixtures with smokeless, particle fallout proof burning". The key concept relative to CLM burning interest was, of course, the term "mud".

2. The Calgary office, when phoned were not familiar with the burner and referred me to Schlumberger, New York, or Flopetrol Melun in Vaux-le-Percil, France.

3. Starting my contact efforts with the Schlumberger H.Q. in New York, I finally came into telephone contact with the Flopetrol Manager, Mr. Gilbert Prongué in his Houston, Texas office.

4. I outlined EMR's interest in atomizers suitable for CLM, brought in the Flopetrol "mud" concept, and stated the minimum hard facts which were required to appraise the Flopetrol, which data would be covered by our Confidentially Protection letter.

5. Mr. Prongué expressed much interest and requested a letter covering the points of our discussion which I mailed on July 17, 1983 (see copy attached) and included a copy of the DSS letter of confidentiality.

6. On follow up some weeks later, I learned from Mr. Hillman that he had received my correspondence and had transferred it to the Johnston Macco office in Houston, as Mr. Prongué was in Europe until September 15th, with a request that they contact me.

7. I received a letter from Mr. G. Willcox of Johnston Macco, Houston, who is Sr. Staff Engineer for North American Operations for Flopetrol (see copy of his letter of August 9, 1983, attached).

8. With his letter Mr. Willcox had attached a Flopetrol Buletin from which I have photocopied four relevent pages for which see Bulletin 12.

9. The bulletin shows that the burner (assembly) is essentially a waste fuel burner requiring a) the injection of diesel oil into the hydrocarbon refuse "mud"; b) a sub flame to ensure particle burn-out; and c) a water ring to prevent smoke smoke (and to reduce radiated heat).

10. Presuming oil field "mud" and CLM burning requirements are similar (to a presumed reasonable degree). The data of relevance from the Bulletin sheets and particularly the sheet entitled "Specifications" are

	Capacity USgph	Fuel Pressure PSI	Atomizer Press. PSI
Min.	175	150	50
Max.	8750	600	100

11. Atomizing air flow rate is given as 350 SFCM at "low" oil rates.

12. Assuming a "low" oil rate to be (say) 500 USgph the specific atomizing air assumption (for a CWM) is:

$$\frac{350 \times 60 \times .076}{500 \times 8.33 \times 1.19} = .32 \text{ lbs./lb. fuel}$$

12.1 If 350 SFCM is required for the min. cap. of 175 USgph the specific atomizing rate is:

$$\frac{500}{175} \times .32 = .81 \text{ lb./lb. fuel}$$

13. The Flopetrol Bulletin (see page 2 in Bulletin No. 12) states that the Flopetrol atomizer "has been designed to allow the passage of solid particles up to 1/4" dia. This is approx. a median value of the nozzle diameters of the types reviewed in my overall report.

14. Judging from the longitudinal sectional view of the Flopetrol atomizer (see Bulletin 12 page 2) there appears to be design "similarities" between Flopetrol and Atlantic Research (Fig. 6); ICL (modified by FPLC) (Fig. 9); Forney (Fig. 12); Vortometric (Fig. 18); Flosonics (Fig. 21); W.N. Best (Fig. 26)

14.1 Of course only on examination of the manufacturer's atomizer drawing, and demonstration tests of many atomizers would be required to establish the degree of similarity for boiler application considering the flame dimension limitations in boiler work.

15. From the last paragraph of Mr. Willcox's letter Flopetrol say they would be interested in arranging for a test on CWM. From my previous conversation with Mr. Prongué I undrstand that such a test would be carried out in Canada or at the API Test Institute in San Antonio, Texas.

RALPH GROSSMAN

STUDIES AND CONSULTATION IN PROBLEM AREAS OF
FUELS, COMBUSTION AND AIR QUALITY

P.O. BOX NO. 70
TOWN OF MOUNT ROYAL, MONTREAL, QUE. H3P 3B8
TEL. (514) 738-5487

STUDIES

July 17, 1983

Mr. Gilbert Prongué
Flopetrol Co.,
1400 Broadfield Ave., Suite 110
Houston, TX 77084 U.S.A.

Dear Mr. Prongué:

In our telephone conversation last week I stated that I was a combustion specialist serving as a consultant under contract to the Canadian Government Department of Energy, Mines & Resources, Canmet Division. Dr. Horace Whaley of the Canadian Combustion Research Laboratory is my Science Authority.

I mentioned also, Mr. Prongué that my work was directed to acquire technical data on burner-atomizer designs which had proven record in the burning of coal-oil mix, or coal-water mix (or both), or which, in my opinion, could be developed into successful coal-liquid-mix atomizers.

My attention was drawn to your Flopetrol crude-mud-water burner, as used in oil fields, from an ad in a technical magazine, a copy of which I am enclosing.

There would appear to be an intriguing possibility, from the wording in the ad, that Flopetrol could be a potential candidate for development (or direct use) as a coal-liquid-mix burner.

I would appreciate it very much if you could send me a bulletin on the Flopetrol, and particularly a sketch of the atomizer showing the operating principle. The only number and other data I would require at this time are the following:

a) Total area of exit orifices for a given maximum flow rate.

b) Atomizing fluid type:
b.1) Can dry saturated steam, be used instead of air?

c) Consumption of air (or steam) atomizing fluid per lb. fuel.

d) Pressure range of atomizing fluid.

e) Temperature required in the atomizing fluid.

... /2

f) Capacity range covered by your burner models in barrels or U.S. gallons per hour.

g) Existing atomizer metallurgy.

h) Willingness of Zink to develop other metallurgy, e.g. tungsten carbide or ceramics, for the whole atomizer or as inserts to abrasion sensitive areas.

i) Turn down capability of a given burner size.

Of course, also, information that you may have of experience with operation with abrasive containing petroleum fuels would prove of much value, especially if the nature and % content (by weight) of the abrasive material, could be given.

All information you may send me will be treated confidentially as per the letter attached by the Canadian Government Department of Supply & Services originally signed by the Science Procurement Manager.

You mentioned, Mr. P.cngué that you believe that it might be possible to arrange a test of the Flopetrol at the API Test Centre in San Antonio, Texas, or at some location in Canada with a coal-water-mix fuel. This fuel would be a water dispersion of coal ground to pass approx. 70%-75% over 200 mesh and treated with the addition of an additive to maintain dispersion in the liquid. Such a fuel would be a proprietary product of manufacturers such as Carbojel, Gulf & Western, Slurry Tech, Atlantic Research, ARCO, or others. The coal/water or ratio, by weight, would not be less than 70/30.

I look forward with pleasure to receiving your information and trust that we may have the occasion to meet.

Yours sincerely,

Ralph Grossman

cc Dr. Horace Whaley
Canadian Combustion Research Laboratory

FLOPETROL JOHNSTON
Schlumberger

1400 BROADFIELD • SUITE 110 • HOUSTON, TEXAS 77084
TELEPHONE (713) 492-6900 • TELEX 794546

Mr. Ralph Grossman July 29, 1983
P. O. Box No. 70
Town of Mount Royal
Montreal, Quebec H3P 3B6 USC/83/244

Reference: your letter of July 17

Subject: Flopetrol Burners

Dear Sir:

Mr. Prongue is presently in Europe on vacation, so I have turned your request over to Flopetrol Johnston North America and asked that they contact you.

Mr. Prongue and I represent Flopetrol Johnston outside the U.S. and Canada, while Flopetrol Johnston headquartered in Sugar Land, Texas, is responsible for the U.S. and Canada.

Someone will soon be in contact with you regarding your burner requirements.

Yours truly,

G. L. Hillman

GLH:jkd

CC: Pending File
Chrono

JOHNSTON-MACCO
Schlumberger

August 9, 1983

Mr. Ralph Grossman
P. O. Box No. 70
Town of Mount Royal
Montreal, Quebec, Canada H3P 3B8

Dear Mr. Grossman,

We appreciate your interest in our Mud Burner for possible application in burning coal-oil mixtures. We have enclosed a brochure which gives a description and operating characteristics of our burners. As to the possibility of developing a special burner or doing extensive modification of our existing product, we find ourselves faced with somewhat of a conflict - a desire to be of service in your project opposed by the need to maintain the confidentiality of proprietary information and the dilution of our Engineering resources.

While we have a fairly large Engineering department, their efforts, by necessity, must be focused on developing tools that give us a technological edge in our commercial services. These services are, in turn, devoted to providing our clients the most accurate reservoir information possible. Our aim is to develop tools and services that are proprietary, that is, not available from any other source.

We are confident that you would respect the confidentiality of any information that we might provide you. However, it is our policy not to disclose detailed design and manufacturing data. While it might be possible to circumvent this issue, the availability of engineering resources for this specialized project presents a real problem. Unfortunately, we are not in a position to offer the kind of technical support that your project deserves.

In your letter to Mr. Prongue, you discussed the possibility of testing our burners with a coal/water mix. If such a test is planned, we would be pleased to discuss arrangements to make one of our burners available.

Sincerely,

M G Willcox
M. G. Willcox
Sr. Staff Engineer

cc: Tom Grace
Grady Hillman

Sonic Energy Combustion Systems Inc. (Subsidiary of Sonic Engineering Energy Co.) Wilmington, Delaware

Phone discussion date: 14-7-83 Mr. Robert Schurig Vice-President and General Manager.

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1. Mr. Schurig confirmed that the trouble expeienced at the Halifax Shipyards test when the Sonicore resonator experienced a quite short life, was due to the 3-arm support attachment for the resonator, with the supports and resonator directly in the path of the fuel stream.

2. This problem can be seen in Figures 27.1 and 27.2 obtained from Sonic Energy Combustion Systems Bulletin S-1000.

3. Sonic Energy Combustion Systems, said Mr. Schurig, had modified the design of the resonator by the use of Stellite alloy steel and by strengthening the methods of attachment of the three support arms.

4. The basic design is still the same.

5. Sonic Energy Combustion Systems have not done R & D on further modification of the Sonicore for use with CLM fuels, nor had they any R & D plans in this direction.

6. The units though are sold through agents and it was possible that one or more of these agents may have attempted CLM work, but not to Mr. Schurig's knowledge.

7. Mr. Schurig mentioned that in 1978, under D.O.E. auspices, that Accurex ran a test at a General Motors plant on 50/50 COM with a Delavan and Sonicore atomizer, and found significant erosion with the Delavan and "nil" erosion with the Stellited Sonicore unit. No other operating or design data were given to me.

7.1 In this test, said Mr. Schurig, the NO_x was "higher because of 'higher' combustion temperatures", but the NO_x ppm was still "within the EPA Code".

8. The Sonicore may well be doing an excellent job on oil, but in my opinion, it is doubtful that the pursuit of more data would give the unit prominent ranking for CLM work.

PEABODY ENGINEERING CORP.
Stamford Conn.

Phone discussion date: 18-7-83 - Mr. Roy Frauenhofer
Supervisor Fuel Equipment

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1. Mr. Frauenhofer stated that, to his knowledge there were no demonstration developments since the trials at the Ontario Research Foundation,1) and those at the Atlantic Research Foundation.2)

2. Peabody themselves have not done, nor is it known that they will do, R & D on their atomizer for use with COM or CWM fuels.

3. The only R & D that has been done (and is possible still in progress) is that by the Florida Power Corporation at their Paul Bartow utility plant in St. Petersburgh, FLorida - which matter is covered in my report - Section No. 17.

4. On September 27, 1983 I contacted Mr. H.E. Higgins, Technical Services Supt. of the Florida Power Corp. who gave as much valuable information on their technical developments since my visit to them last July 23, 1982.

4.1 I will report on this information as an addendum to my Report No. 17 on F.P.C.

1) L. Bruno and A.S. Deshpande, Ontario Research Foundation and Dr. Horace Whaley, Canadian Combustion Research Laboratory in the Fourth International Symposium on Coal Slurry Combustion, May 10-12, Orlando, Florida.

2) Atlantic Research Laboratory Technical Report No. 33 (NRCC No. 11916, Halifax, N.S. 1981).

John Zink Company
Tulsa, OK

Phone discussion dates: John Zink Canada
12-7-83 Mr. John Burrows, Zink Burner Specialist

4-8-83 Mr. Peter Harris, General Manager, John Zink Canada

12-2-83 Dr. Richard Waibel, Technical Dir., Burner Divison, John Zink, Tulsa, OK

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1. On initial contact with Mr. John Burrows of Zink Canada, he suggested I contact Dr. Richard Waibel, Tech. Dir. of the John Zink Company of Tulsa. OK.

2. I spoke with Dr. Waibel and described the CLM data requirements of E.M.R.

3. I said that I had a 25 column technical questionnaire devised to obtain data on burners from which an appraisal could bemade for its suitability for CWM applications.

4. I outlined the main points of the technical atomizer design and operating characteristics data needed. Dr. Waibel stated that he could see no objections to submitting the data, but asked that I send him a copy of my questionnaire, on receipt of which he would consider the propriety of sending me a coy of his current standard atomizer design, which I had requested.

5. It was an interesting coincidence, said Dr. Waibel, that my call came as he was just starting work on an atomizer design suitable for the burning of a petroleum coke-water mix.

6. I sent a copy of the questionnaire to Dr. Waibel via John Burrows of John Zink Canada (see my letter attached).

7. Dr. Waibel confirmed receipt of my questionnaire and of his CLM program in his letter to me of August 9, 1983 (copy attached).

8. It is interesting that the Zink development will be based on an external atomizing design with steam as the atomizing fluid.

9. It will be interesting to find out from Dr. Waibel, why steam was selected (perhaps because of availability?) and whether he considered that air could also be used as an atomizing fluid, and whether he intended to make such experiments. Availability of both atomizing fluids would provide greater applicability to plants

where only air or only steam was practical. There is also the question of economics as analysed in Appendix No. 9. A further contact with Dr. Waibel in December is, of course, indicated.

RALPH GROSSMAN LIMITED

STUDIES AND CONSULTATION IN PROBLEM AREAS OF
FUELS, COMBUSTION AND AIR QUALITY

P.O. BOX NO. 70
TOWN OF MOUNT ROYAL, MONTREAL, QUE. H3P 3B8
TEL. (514) 738-5487

STUDIES

July 17, 1983

John Zink Canada
1565 Brittania Road East, Unit 2
Mississauga, Ontario
L4W 2V6

Attn: Mr. John Burrows - Mgr. of Engineering Applications
Re: John Zink Burners
for Coal-liquid-mix firing
Coal-oil-mix 50/51 - by weight
Coal-water-mix 70/30 by weight

Dear Mr. Burrows:

Following our telephone discussion last week, I contacted Dr. Richard Waible at your Tulsa, Oklahoma office. He said that he would be agreeable to answer, to the extent possible, the essential questions in my tabular questionnaire re:

atomizing fluid - i.e. air or steam or both
% O_2
% carbon burn-out
Gross area of exit orifices (to determine exit velocities).

All information provided by John Zink will be held confidential as covered by originally signed letter of the Canadian Department of Supply & Services, copy of which is enclosed.

I am also enclosing the two sets of tabular set questionnaire forms: Table 1, pages 1-4 incl., columns 1-26 incl. in atomizer technologies; and Table 2, pages 1 & 2, columns 1-17, covering operating characteristics.

These are the questionnaires which Dr. Waible said he would answer, to the extent possible. If direct answer is not possible, then possibly a separate statement of the R & D. in progress, or to be established, could be made and which would be helpful.

I look forward with much interest to receipt of the Zink data.

Yours sincerely,

Ralph Grossman

cc Dr. Horace Whaley
Canadian Combustion Research Laboratory

JOHN ZINK COMPANY

ENGINEERS AND MANUFACTURERS SERVING THE WORLD IN ENERGY TECHNOLOGY

August 9, 1983

Mr. Robert Grossman
P. O. Box No. 70
Town of Mount Royal
Montreal, Quebec H3P 3B8
CANADA

Reference: Slurry Fuel Atomization Questionaires

Dear Mr. Grossman,

John Zink Company is currently engaged in a program to develop an atomizer/burner for petroleum coke/oil mixtures. This atomizer will be subjected to the same types of erosive wear that occurs when firing coal/oil or coal/water mixtures and so we feel that it will also be suitable for these fuels. We currently are fabricating these tips. Erosion and spray testing of the atomizers is scheduled to begin in September and combustion testing of a 25 MM BTU/HR burner is scheduled for December. At that time we will also conduct a short, 500 gallon test burn with a coal/water mixture that we currently have on hand.

Our initial designs will employ steam atomization for the coke/oil mixture and are of an external atomization design. We have not yet tested them so we do not know the steam consumption, pressure drops or exit velocities necessary for good performance. This data will be available in December.

I am sorry that we are not prepared to answer many of your questions at this time, however, we will be pleased to provide the information as soon as it is available.

Sincerely,

JOHN ZINK COMPANY

Richard T. Waibel

Richard T. Waibel
Technical Director
Burner Division

RTW/jgd

cc: Peter Harris/JZ Canada

4401 S Peoria • Tulsa OK 74105 • Phone 918 747 1371 • Telex 497414

TABLE 1 - PAGE 1
SUMMARY OF CLM BURNER DATA

1	2	3	4		5			6				7
Sect. No.	Manufacturer	Atomizer Model	1) Type of Atomizing		Burner CLM Capability			Atom.Medium for CWM (or #6 oil), PSI				Capacity Range 10^6 BTU/Hr.
			Internal	External	CWM	COM	COW	H.P.Stm.	H.P.Air	L.P.Air	Ret.Flow Mech.	
1	Babcock & Wilcox Co.	"T"	X T Jet		X			>100	>100	>35 4 PSI at Tip End	NO	1.0 to 50 (to 150 future)
2	Hauck Manufacturing Co.	"Cup" Type	X Hybrid	X Hybrid	No Exper. But Pot.	X		25 - 50	25 - 50	1 - 2	No	0.5 to 160
3	Process Combustion Corp.	Urquhart "Vortex Cup"		X	Pot. No Exp.	Pot. No Exp.	Pot. No Exp.	15 - 150	15 - 80	No	No	1.0 to 150
7	National Air Oil Burner Company	"SA"	X Cavity		Pot. No Exp.	Pot. No Exp.	Pot. No Exp.	10 - 100	10 - 100	No	No	1.5 to 160
8	Faber Burner Division of Keeler-Dorr-Oliver Co.	Steam or W.R.M.A.	X Tip		Pot. No Exp.	X	Pot. No Exp.	15 - 150	15 - 150	No	300 - 700 at inlet min. 50 on return	1.5 to 150
11	Atlantic Research Corp.	ARC		X	X		X	15 - 100	15 - 100	30	No	.3 to 3

a) Exp. = Experience

b) Pot. = Potential

c) Blank space = Information not available

1) See attached sheet for foot notes and other data.

TABLE 1 - PAGE 2
SUMMARY OF CLM BURNER DATA

1	8			9	10	11	12	13	14	15	16
Sect. No.	CFM or Weight Atom. Fluid Per Lb. Fuel 5)			COM/CWM Press. at Burner Inlet, PSI	Vol. CWM Cu.Ft./Sec.	Vol. Emulsifying Atom.Stm.or air Cu.Ft/Sec.	Total Emul. (of CWM) Vol.Cu.Ft./Sec	Area of Orifice(s) Sq.Ft.	Exit Velocity Ft./Sec.	Mixing Chamber Press.-PSI	Angle θ of Incidence Fuel Stream
	H.P.Stm.	H.P.Air	L.P.Air								
1	.10 to.15	N/A	N/A	*) f(Vis) max. 100 psi atomizer inlet	@500 USgph 0.0185	0.89 (Steam)	0.91	.0046 (4)	198	Est. 50	Est. 45°
2			.20 lb.	2 - 8	@500 USgph 0.0185	0.13 (Air)	0.15	B-.003 Cup-.023	50 7	Est. 1.5	B 180° Cup 45°
3	Variable 0.15 to 0.5 relative atom. press range 150 psi to 15 psi.		No	5 - 115 psi f(Press. drop in burner from inlet to atom. tip.)	@500 USgph 0.0185 At 100 psi atomizing press.	External (Air)	CWM only 0.0185	See Appendix 1) A-.00088 B-.00022 C-Surface	 21 84 11	- Fig. 3 N/A N/A N/A	180°
7	.3 lb.	.35 lb.	No	1 - 100	@240 USgph 0.009	1.29 (Steam)	1.299	0.002 greater area possible	650	Est. 50	30°
8	.15	.15	No	25 - 125	@150 USgph 0.0056	0.406 (Steam)	0.412	0.0012	343	Est. 50	Est. 30°
11			.3 to .5	N/A	@20 USgph .00074	External (Air)	.00074	.000192	3.85	External	180°

*) f = function

TABLE 1 - PAGE 3
SUMMARY OF CLM BURNER DATA

1	17	18	19	20		21				22	
				Atomizer Material		Nozzle Orifices				Adjustable Vane Air Control	
Sect. No.	Erosion Index (4) Clm 14 x (Clm. 10/Clm.12) + Sin θ -1 (Clm. 16)	Vis. Required at Shear Point SSU or C.Poise	Turn Down Capability ratio CWM	Present	Future	Burner Cap.-USgph	No.	Dia. Ins.	Area Sq.Ft.	Secondary	Tertiary
1	5.53	800 - 1600 c.Poise	CWM -2 1/2:1 #6 oil 10:1	Tool steel	Alloyed ceramic total atom.or inserts	500	8 -12	Est. .32"	Est. .0046	X	X
2	6 Sector B 8.41 Cup C See Fig. 2.1	COM oil at 230°F = 150 SSU approx.	#6 oil/gas 10:1 COM 2 1/2:1	Tool or S.S	As req'd. Total Atom. or inserts	500 Nozzle Cup	1 1	3/4 1 1/8	.003 .023	X	Optional
3	21 - Sector A 84 - Sector B 11 - Cup C See Fig. 3	No CLM experience- but #6 oil (COM) would require 100 SSU.	#6 oil-5:1 CLM-N/A	Cast Iron	As req'd. Total atom. or inserts	500 Nozzle A Nozzle B Cup	1 1 1	0.4 0.2 1.5	.00088 .00022 0.04	No	No
7	6.5	Max. with high flow atom. steam - 2500 SSU.-Std.max. 300 SSU	#6 oil 4:1 CLM -N/A	Various metals	Stellite, cerametals, et al.	240	24	1/8	0.002		
8	6.6	Stm.At.-250SSU W.R.M.A.-150SSU Values are Max.	2 1/2-3:1	Stainless Steel	As required	150	10	.149	0.0012	X	X
11	3.85	Insuff.info available. est.test temp. 70°F.	CWM 10:1 Oil 10:1	304 - 316 Stainless	As required	20	1	3/16		Yes	No

TABLE 1 - PAGE 4
SUMMARY OF CLM BURNER DATA

1	23				24			25		26		
	CWM Development Program				Costs			Criteria for Atomizer Rejection		Capability For Other Fuels		
Sect. No.	Tech. Support	R & D	Testing	Trouble Shooting	Capacity 10^6 BTU/Hr.	Atomizer Only	Complete Burner	Special	General	Oil	Gas	Comb. Oil/Gas
1	X	B & W on going	X	X	50 150	\$ 5,000 5,000	\$25,000 25,000	10% area loss as calipered.	Comb.changes ; Vis: % O_2; exhaust opacity; % carbon burnout;flame down;change fuel flow rate.	Sep. gun	Spud gas ring.	Sep. gun & ring.
2	X	By Agreement	X	X	50 190	\$ 7,000	\$28,000 64,000 Incl.F.D. Fan.	Insufficient field experience with COM - none with CWM.		Yes	Yes	Yes
3	X	By Agreement	X	X	50 Includes Combustion Toroidal Chamber		\$50,000	No CLM field experience.		Yes	Yes	Yes
7	X	By Agreement	X	X	36 - 50	\$ 1,400 tool steel	(6)	No CLM field experience.		Yes	No	No
8	X	By Agreement	X	X	15 - 20	Not recommended	\$ 5,000			Yes - If COM gun	Ring Burner	Yes - if COM gun
11	X	In being by ARC	In boiler plants & ARC test unit.	X	Only one unit made Not for sale			Insufficient burning hours for realistic determination		Yes	No	Oil only

TABLE 2 - PAGE 1
OPERATING CHARACTERISTICS WITH COM AND CWM

1	2	3	4	5		6		7	8	9	10	11
Sect. No.	Fuel	Coal Content By Weight % Range	Rate of Firing 10^6 BTU/Hr.	Fuel Temperature at Burner Range - °F		Combustion Air Temperature °F		At Nozzle Apparent Vis. SSU/c.Poise	Type of Spray Pattern	Flame Dim. Relative #6 Fuel Oil	Flame Stability	Particle Size Distribution
				Min.	Max.	Min.	Max.					
1	CWM	70	8	212	235	600		500 - 1600 f (CWM quality)	Hollow	Similar	f(CWM; atomizer; air temp.;furnace temp.)	To be determined.
2	COM	50	9.6 to 38	230°	250°			COM-#6 oil component at max. 150 SSU	Hollow	Bushier	OK at 230°F minimum	N/A
3	----------------No CLM Field Experience ----------------											
7	----------------No CLM Field Experience ----------------											
8	COM	50	13.10^6	320°				#6 oil COM at 320°F at nozzle = 100 SSU (350°F at burner package inlet) Was this asphalt?	Hollow	Similar	Good at req'd COM temp.	

TABLE 2 - PAGE 2

OPERATING CHARACTERISTICS WITH COM AND CWM

1	12	13	14	15	16		17
Sect. No.	Is Auxiliary Fuel Required	O_2 Range %	Carbon Burn-Out %	Control Of Spray Pattern	Atomizer Life, Hrs.		Basic Problems
					Present	Near Future	
1	<50% rating - certain fuels Others - none		Target-90%	By burner design.	300	Est. 600	More R & D with larger burners on longer runs, to: evaluate atomizer life, % carbon burn-out; slagging; fouling; stability; % boiler de-rating.
2	Not on COM.		Complete	Burner design.			COM pressure and temperature problems due to problems in supply system.
3	--------------------No CWM Field Experience--------------------						
7	--------------------No CWM Field Experience--------------------						
8	Not on COM.		N/A	Nozzle orifice design - no. of orifices; dia. and angle.	Inadequate field experience		Getting to proper COM operating temp. CWM. Test in England to start soon, news in about 2 months.(Oct. 30/82.)

TABLE 1A- PAGE 1A
SUMMARY OF CLM BURNER DATA

1	2	3	4		5			6				7
			Type of Atomizing		Burner CLM Capability			Atom. Medium for CWM (or #6 oil), PSI				
C Sect. No.	Manufacturer	Atomizer Model	Internal	External	CWM	COM	COW	H.P.Stm.	H.P.Air	L.P.Air	Ret.Flow Mech.	Capacity Range 10^6 BTU/Hr.
16	I.C.L. - England, C/O Florida Power & Light Co. - Sanford Plant	I.C.L.		X		X		100 - 150	90 - 100		N/A	3 to 200
17	Peabody "Bullet" C/O Florida Power Corp. Bartow Plant, St. Petersburg	"Bullet" Atomizer Dudley-Higgins modification	X			X		170 max.	170 max.		N/A	2 to 90
19	Forney Engineering Co.	CWM Air Atomizing	Hybrid See Fig. 12		X	X	X	To be Researched	70	Forney Verloop	Yes-but not for CWM	20 to 250
20(a)	North American Manufacturing Co.	Bull.56.42 Full Emulsion Type	X		R & D	test with LAP atomizer	R & D	100 psi at burner In. 16-80 psi at atom. inlet	repeat steam		N/A	Max. present: 60 Future: 120
20(b)	North American Manufacturing Co.	Bull. 56.43 Tip Emulsion Type	X		R & D	R & D test definite	R & D	100 psi at burner inlet 35-65 psi at atomizer inlet	repeat steam		N/A	Max. present: 60 Future 120
20(c)	North American Manufacturing Co.	Bull. 56.22 External atom. Type		X	R & D	R & D test definite	R & D	15-125 psi at atomizer inlet	15-125 psi at atomizer inlet	R & D	N/A	2 to 38

TABLE 1A- PAGE 2A
SUMMARY OF CLM BURNER DATA

1	8			9	10	11	12	13	14	15	16
Sect. No.	CFM or Weight Atomizing Fluid per lb. Fuel			COM/CWM Press. At Burner (1) Inlet, PSI	Vol. CWM Cu.Ft./Sec.	Vol. Emulsion Atom. Stm. or air Cu.Ft./Sec.	Total Emul. (or CWM) Vol. Cu.Ft/Sec.	Area of Orifice(s) Sq.Ft.	Exit Velocity Ft./Sec.	Mixing Chamber Press.-PSI	Angle θ of Incidence Fuel Stream
	H.P.Stm.	H.P.Air	L.P.Air								
16				85 - 135	.05 @1350 USgph	External	.05 @1350 USgph	.0076	6.6	External	60°
17	0.12-0.16		No	COM:- 40 - 150	.022 @600 USgph	1.59	1.612	0.003	537	50 (est.)	35°
19		.25		Max. - 70 Min. - 40	0.0164 @442 USgph	0.915	0.93	.00245	380	(Est.) 50	Est. 45°
20(a)	.48 lb. at 80-100 psi max.	.81 lb. at 80-100 psi max.	No	100 psi at burner inlet 5.5 - 65 psi at atomizer inlet	.015 (@400 USgph)	steam - 2.96 air - 2.24	Steam 2.975 air 2.26	.0055	atm -541 air 410	(Est.) 50	180°-sgl.hole Est. 30°-multi-hole
20(b)	.15 to .36 lb. for 2:1 T.D. at 80 psi max.	.23 to .55 for 2:1 T.D. at 80 psi max.	N/A	100 psi at burner inlet. 30 - 65 psi at atomizer inlet	.015 (@400 USgph)	steam - 0.91	0.93	.0023	404	(Est.) 50	180° sgl.hole Est. 30° - multi-hole
20(c)	.24 for 2.5:1 at 85 psi	.37 for 2.5:1 at 85 psi	N/A	5 - 10 psi	.00935 (@250 USgph)	- - -	-------	.00136	6.88	------	180°

TABLE 1A- PAGE 3A

SUMMARY OF CLM BURNER DATA

1	17	18	19	20		21				22	
Sect. No.	Erosion Index (4) Clm.14 x (Clm 10/Clm.12) + Sin θ^{-1} (Clm.16)	Vis. Required At Shear Point SSU or c.Poise	Turn Down Capability Ratio CWM	Atomizer Material		Nozzle Orifices				Adjustable Vane Air Control	
				Present	Future	Burner Cap.-USgph	No.	Dia. Ins.	Area Sq.Ft.	Secondary	Tirtiary
16	6.75	Vis. that is pumpable is burnable	#6 oil-3:1 COM-COW-3:1 CWM - 2:1	Special Alloy Material	As R & D may develop	1350 low cap.	1 Confidentiality	1.18		X	
17	9.05		COM - 3:1	Tool steel	Alloy	@ 120 MW 721	8	0.266	0.003	X N.B.: Using existing B & W registers	X
19	8	Rheogram N.A. Atom. Press.as required for vis. at shear point	CWM - 2:1 #6 oil- 6:1	Tool steel	As R & D shows need.	442	--Annulus -----		.00245	X Primary	X Secondary
20(a)	Sgl.hole -steam -2.71 -air -4.71 Multihole -steam-2.70 - air -4.70		Est.3.5:1	Stainless or higher alloys	As R & D will determine - Incl.ceramics	400			0.0055	Blast gate control of combustion air into N.A. burner body 1-8 psi pressure.	
20(b)	Steam sgl.hole - 6.46 multi hole - 8.6 Air multi hole - 8.5		Est. 6:1	ditto	ditto	400			0.0023	----ditto-------	
20(c)	6.88		Est. 4:1	ditto	ditto	250	1	0.5	.00136	----ditto --------	

TABLE 1A- PAGE 4A
SUMMARY OF CLM BURNER DATA

1	23				24			25		26		
	CWM Development Program					Costs		Criteria for Atomizer Rejection		Capability for Other Fuels		
Sect. No.	Tech. Support	R & D	Testing	Trouble Shooting	Capacity 10^6 BTU/Hr.	Atomizer Only	Complete Burner	Special	General	Oil	Gas	Comb. Oil/Gas
16	F.P.L.C testing	only do their own and R & D.		private				Point where flame dimension change cannot be tolerated.	Stack exhaust opacity; % carb. burn-out; flame stability.	X (COM gun)	X	X (COM gun)
17	CWM under consideration							------------Experimental---------------- But consider Sidewall impingement would be a critical factor.		X	Ring Gun burner	ring burner plus COM atomizer
19	X	X	X	X	40		Chatham Proposal	Insufficient field experience		Separate Gun	Ring Gas Burner	Separate Gun & Ring Gas Burner
20(a)	X	X	X	X	30	$495.00				Change atomizer	Separate gas burner	Atomiser change plus separate gas burner
20(b)	X	X	X	X	30	$1265.00 plus $300 for T.Carbide inserts				Change atomizer	Separate gas burner	Atomiser change plus separate gas burner
20(c)	X	X	X	X	37.5	$585.00				Yes	N/A	N/A

TABLE 2A- PAGE 1A

OPERATING CHARACTERISTICS WITH COM & CWM

1	2	3	4	5		6		7	8	9	10	11
Sect. No.	Fuel	Coal Content By Weight % Range	Rate of Firing 10^6 BTU/Hr	Fuel Temperature at Burner Range - °F Min.	Max.	Combustion Air Temperature °F Min.	Max.	At Nozzle Apparent Vis. SSU/c.Poise	Type of Spray Pattern	Flame Dim. Relative #6 Fuel Oil	Flame Stability	Particle Size Distribution
11	CWM	60% - 63% no surfactants	1	Ambient.	Effect of higher temp. to be studied.	Helped promote combustion.	600°F	Possibly 500 c. Poise. No precise determination.	Semi-Hollow	Filled test furnace 20" ∅ x 9'.0" long.	Good	80% through 200 mesh - smaller size not tried.
16	COW COM CWM	Coal 58% Oil 40% Water 2% Coal 50% Oil 50% R & D	200 per burner	COM - preheat to suitable carrier oil viscosity.		COM	d) 555°F	COM-(Presumed) 150 SSU (oil)max. CWM - N/A	Hollow	Similar	Good after boiler brought up to temp. by #2 oil start-up.	
17	COM	50% 98% over 325 mesh	22 - 90 per burner		274°F		550°F	Apparently <150 SSU	Hollow	No side wall impingement with COM	If atomizer not eroded flame is stable.	
19	CWM 80% 200 mesh	70	40	100	N/A	250 Still under R & D Study	700	N/A	Hollow	Similar	Good	
20(a)	COM	Only CLM experience was a very short time firing of a 50/50 COM with a low air pressure design burner to prove combustion capability.										
20(b)	COM	50/50	Burners with atomizer models 56.42 & 56.43			R & D to be carried out.						
20(c)	COM	50/50	Burners with atomizer model 56.22/23 - R & D to be carried out.									

(d) - station Wind box temperature

TABLE 2A- PAGE 2A
OPERATING CHARACTERISTICS WITH COM & CWM

1	12	13	14	15	16		17
					Atomizer Life, Hrs.		
Sect. No.	Is Auxiliary Fuel Required	O_2 Range %	Carbon Burn-Out %	Control of Spray Pattern	Present	Near Future	Basic Problems
11	Yes (Gas)	3 1/2 - 4	90 - 95	Variable section of secondary air. Control system.	Insufficient data.		Preheat of secondary air needed. Internal recirculation desirable. ARC swirl design seems desirable.
16	Yes - at start	3% - 4%	95	Press. diff. and cone angle. Presumably P of atom. fluid Vis. COM and angle of cup at atomizer tip.	1000 with latest I.C.L. burner.	Target 2000 Hrs.	See paper on initial Sanford COM trials by A.J.Kasprik, F.P.L.C.: H. Cousilla, Bechtel Power Corp.; P. Kartzke, Bechtel Power Corp. (Tests conducted early 1980 to Sept. 1980).
17	Cold start with #6 oil, then COM blended in.	Approx 1%	99	By tip design	Still experimental (2 month trial to date).		N.B.: COM supplied to Bartow by Comco - a subsidiary of F.P.C. Economics: Atomizer Cost vs. Life
19	Ignitor only till operating temp. reached	Min. 1½ normal 3	N/A R & D (Chatham)	Cone atomizer distributor plus primary air flow through diffuser.			Ash ringing as observed on short run on cylindrical test furnace at 40.10^6 Btu/Hr. (Relationship to a given sustained combustion air temp. should be established).
20(a)	R & D to start in January 1983 with 50/50 COM.						
20(b)	R & D to start in January 1983 with 50/50 COM.						
20(c)	R & D to start in January 1983 with 50/50 COM.						

TABLE 1B- PAGE 1B
SUMMARY OF CLM BURNER DATA

1	2	3	4		5			6				7
Sect. No.	Manufacturer	Atomizer Model	Type of Atomizing		Burner CLM Capability			Atom. Medium for CWM (or #6 oil), PSI				Capacity Range 10^6 BTU/Hr.
			Internal	External	CWM	COM	COW	H.P.Stm.	H.P.Air	L.P. Air	Ret. Flow Mech.	
21	N.R.C. '- Fluid Kinetics Inc.	Flo-Sonics	Partial See Appendix #4 & Figure 2.2 (Atlantic Research - N.R.C. Tech. Paper #33)	Partial	to be tested		Yes		100	No	No	1) COW 6 - 180 CWM 4.5-130 1) 50:15:25mix
25 & 26	Conamara Ltd.	Vortometric Type	Internal with divergent nozzle		R & D	X	R &D	35 - 75	35 - 75	Air assist to mech. atom. 4-0 psi.	No.	1-250
27	C.E. Canada	Special for 22.5 MWe at Chatham, N.B.	Internal & Divertor . "Cup"	Quarl plus C.F. air may assist atomizing.	X	X		50 - 225	25 - 100		St. mech. - 1000 psi Input-600 psi output	1-100 CWM Oil/gas - 1-180
28	W.N. Best - Division of Preferred Utilities	Calorex Series 50		Off "lip" trough					100		No	#6 Oil - sludge 30 - 90

TABLE 1 B - PAGE 2 B
SUMMARY OF CLM BURNER DATA

1	8			9	10	11	12	13	14	15	16
Sect. No.	CFM or Weight Atomizing Fluid per lb. Fuel H.P.Stm.	H.P.Air	L.P.Air	COM/CWM Press. At Burner Inlet , PSI	Vol. CWM Cu.Ft./Sec.	Vol. Emulsion Atom. Stm. or air Cu.Ft./Sec.	Total Emul. (or CWM) Vol.Cu.Ft./Sec	Area of Orifice(s) Sq.Ft.	Exit Velocity Ft./Sec.	Mixing Chamber Press.-PSI	Angle θ of Incidence Fuel Stream
21		.09-.15	No	115	0.003 (@81 USgph)	air - .055 (@27.7 psig at throat Pt.2 see Fig. 21)	0.058	5.6×10^{-4} (70% of Gap A)	103.6	13 (Approx.)	Est.45°
25 & 26	0.21	0.25		15 - 60 (#6 oil)	0.005 (@ 134USgph	steam - 0.83	0.835	Div. Nozzle Est.-0.0031 Fuel Orifices 7.10^{-5}	Nozzle 269 Fuel orifices 71	17.8	Div. nozzle Est.-45°∠ Fuel orifices Est.-30°∠
27	CWM 0.12	CWH 0.13		Steam atomizing 40-150 Air atomizing 25-150	0.0231 @ 566 USgpm	Steam 1.27	1-29	1.44^{-3}	898	50	Est.30°
28	#6-sludge 0.135	#6-sludge 0.175		Press. as required to bring fuel to "LIP" (atomizing trough)	0.0115 @ 300 USgph			Effective (i.e.) equivalent LIP area (calc.) 1.15^{-2}	Fuel only	1	Est.30°∠

TABLE 1 B - PAGE 3 B
SUMMARY OF CLM BURNER DATA

1	17	18	19	20		21				22	
Sect. No.	Erosion Index (4)	Vis. Required At Shear Point SSU or c.Poise	Turn Down Capability Ratio CWM	Atomizer Material		Nozzle Orifices				Adjustable Vane Air Control	
	Clm.14 x (Clm 10/Clm.12) + Sin. θ^{-1} (Clm. 16)			Present	Future	Burner Cap.-USgph	No.	Dia. Ins.	Area Sq. Ft.	Secondary	Tertiary
21	7.06			ceramic insert	R & D	81 USgph (erosion test)	Annulus	.89"dia x .0415" width	8.10^{-4} Full area CLM effective $5.6.10^{-4}$	No.vanes	See Fig. 2.2 in Appendix 5 See Calcs,Appendix 5
25 & 26	Div. nozzle - 3.01 Fuel Orifice - 73		#6 oil High press. air or steam 8-10:1 low air press 20:1	Stainless steel - 304 or 310	Silicon-Carbide or ceramics,from R & D	134 (20.10^6 Btu per Hr. #6 oil)	8	.04	7.10^{-5}	Fuel/air mixing function of "toroidal" effect in Combustor/Air design	
27	18	3500 cP at 10 sec.$^{-1}$ 2150 cP at 180 sec.$^{-1}$	steam 2:1 air 4:1	Tungsten carbide inserts	R & D	566	7	.194	$13.5.10^{-4}$	Volume control vanes in air supply ducts.	
28	3		#6 oil 3:1 to 8:1	Can be any required alloy or ceramic		300	Lip		Calculated total equivalent 1.15^{-2}	Register systems can be designed as required	

TABLE 1B - PAGE 4B
SUMMARY OF CLM BURNER DATA

1	23				24			25		26		
Sect. No.	CWM Development Program				Costs			Criteria for Atomizer Rejection		Capability for Other Fuels		
	Tech. Support	R & D	Testing	Trouble Shooting	Capacity 10^6 BTU/Hr.	Atomizer Only	Complete Burner	Special	General	Oil	Gas	Comb. Oil/Gas
21	X	X	X	X			Developed by Mr.Wm. Thayer N.R.C.	See Appendix No. Items 10-12	4 - Sect. III	Gaps may require change	Gas ring with register	As per oil and gas
25 & 26	X	X	X	X	50		$35,000			Separate Atomizer	X	X (With separate oil atomizer
27	X	X	X	X	45	$1350		a) Increased flow (same press.) b) Flame shape distortion	Loss of 5% - 10% in orifice material.	Change guns #6 oil. R&D for oil in CLM atomizer.	Gas ring	See oil plus gas columns
28	X		In 6" dia. X 20' long test furnace	Staff capability	30	$2000 Material "Ileum"	$4500 "Ileum" plus C.S. body.			Subject to R & D		

TABLE 2B - PAGE 1 B

OPERATING CHARACTERISTICS WITH COM & CWM

1	2	3	4	5		6		7	8	9	10	11
Sect No.	Fuel	Coal Content By Weight % Range	Rate of Firing 10^6 BTU/Hr.	Fuel Temperature at Burner Range - °F		Combustion Air Temperature °F		At Nozzle Apparent Vis. SSU/c. Poise	Type of Spray Pattern	Flame Dim. Relative #6 Fuel Oil	Flame Stability	Particle Size Distribution
				Min.	Max.	Min.	Max.					
21	COW	55:15:30	6			(Can be assumed ambient)			Similar to oil only	Held within test furnace 1 metre dia. x 4 m. long	Short 5 hr. test to prove combustion ability. Good flame achieved after modification of register.	
25 & 26	COM	50	20		250	atmos.	atmos.		Hollow	Same	Good	N/A
27	CWM	70	45-50 10^6 BTU/Hr per burner	AMBIENT		250^o F.	550^oF from exist air heater	3000-3500 c Poise	Fireball	Similar to oil	Good	Mean dia. 100 uM
28	#6 oil or sludge								Function of "LIP" design	#6 oil 30.10^6 2'Wx6'L 90.10^6 6'Wx8'L		

TABLE 2B - PAGE 2B
OPERATING CHARACTERISTICS WITH COM & CWM

1	12	13	14	15	16		17
					Atomizer Life, Hrs.		
Sect. No.	Is Auxiliary Fuel Required	O_2 Range %	Carbon Burn-Out %	Control of Spray Pattern	Present	Near Future	Basic Problems
21	Full test on CWM to be carried out in Halifax test furnace (1 m. dia. x 4 m. long) with NRC Flo-Sonics atomizer and with combustion air register designed to provide primary air control and secondary air swirl.						
25 & 26	No	3	99	Nozzle arrangement and toroidal combustor design	N/A	N/A	Insufficient experience on CLM fuels.
27	No	5% - 6% on CWM	98-99	Fireball pattern - held 18" x 24" from tubes			Not yet known in adequate detail. #6 oil will be tried by N.B. Electric Power on CWM guns.
28		4	98	By register design			No CLM experience.

TABLE 8 Page 1
ATOMIZER ASSESSMENT INDEX

Life Atom., Fuel Cons. & Cost; combustion eff.;size coal particle dispersion; actual SO_2; % carbon burn-out;
N.A. = Not applicable Data from Tables 1 - 1A - 1B as of approx. Oct. 1980

Section No.	1) Atomizing Mode	Related Fig. Nos.	Mfrs. Atomizer Life, Hrs.							Mfrs.Estimate of Possible Atom Life, Hrs.						Operating Experience		Particle Size M.D., uM	
			Tool Steel		Alloy		Ceramic			Tool Steel		Alloy		Ceramic					
			com	cwm	com	cwm	com	cwm		com	cwm	com	cwm	com	cwm	com	cwm	com	cwm
3	A A. External	3&3.1																	
Rating #			0	0	5	5	5	5		0	0	0	0	0	0	0	0	0	0
11	A. External	6															x		
Rating #			0	0	5	5	5	5		0	0	0	0	0	0	3	5	0	0
20(c)	A. External	15																	
Rating #			0	0	0	0	0	0		0	0	0	0	0	0	3	0	0	0
16	A. External	9			1000	700^e	1000^e	700^e				2000	0	2000	0	x			
Rating #			0	0	9½	8	7	7		0	0	7½	0	7½	0	0	0	0	0
28	A. External	25																	
Rating #			0	0	0	0	0	0	0	0	0	0	0	3^e	3^e	0	0	0	0
2	B B. Hybrid	2.1														x			
Rating #			0	0	5	5	5	5		0	0	0	0	0	0	5	3*	0	0
19	Hybrid	12														x	x		
Rating #			0	0	5	5	5	5		0	0	0	0	0	0	5	8½	0	0
25-26	B. Hybrid	18			300											x	comb. test		
Rating #			0	0	7½	5	7	5		0	0	0	0	0	0	7	5	0	0
21	B. Hybrid	20					200							200					
Rating #			0	0	0	0	7	5		0	0	0	0	8½	5	7	0	0	0

*) Author's judgement value
e) Estimated value

TABLE B Page 1
ATOMIZER ASSESSMENT INDEX

Life Atom., Fuel Cons. & Cost; combustion eff.;size coal particle dispersion; actual %O_2; % carbon burn-out;
N.A. = Not applicable Data from Tables 1 - 1A - 1B as of approx. Oct. 1980

Section No.	1) Atomizing Mode	Related Fig. Nos.	Mfrs. Atomizer Life, Hrs.						Mfrs.Estimate of Possible Atom Life, Hrs.						Operating Experience		Particle Size M.D., uM	
			Tool Steel		Alloy		Ceramic		Tool Steel		Alloy		Ceramic					
			com	cwm	com	cwm	com	cwm	com	cwm	com	cwm	com	cwm	com	cwm	com	cwm
	A																	
3 Rating #	A. External	3&3.1	0	0	5	5	5	5	0	0	0	0	0	0	0	0	0	0
11 Rating #	A. External	6	0	0	5	5	5	5	0	0	0	0	0	0	3	x 5	0	0
20(c) Rating #	A. External	15	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
16 Rating #	A. External	9	0	0	1000 9½	700^e 8	1000^e 7	700^e 7	0	0	2000 7½	0 0	2000 7½	0 0	x 0	0	0	0
28 Rating #	A. External	25	0	0	0	0	0	0 0	0	0	0	0	3^e	3^e	0	0	0	0
	B																	
2 Rating #	B. Hybrid	2.1	0	0	5	5	5	5	0	0	0	0	0	0	x 5	3*	0	0
19 Rating #	Hybrid	12	0	0	5	5	5	5	0	0	0	0	0	0	x 5	x 8½	0	0
25-26 Rating #	B. Hybrid	18	0	0	300 7½	5	7	5	0	0	0	0	0	0	x 7	comb. test 5	0	0
21 Rating #	B. Hybrid	20	0	0	0	0	200 7	5	0	0	0	0	200 8½	5	7	0	0	0

*) Author's judgement value
e) Estimated value

TABLE B Page 2
ATOMIZER ASSESSMENT INDEX

Life Atom., Fuel Cons. & Cost; combustion eff.;size coal particle dispersion; actual %O$_2$; % carbon burn-out;
N.A. = Not applicable Data from Tables 1 - 1A - 1B as of approx. Oct. 1980

Atom. Mode and Sect. No.	Atom. Fluid Cons. Lb/Lb fuel 5)				Cost Atom. Fluid/Lb Fuel 2)				Exit Velocities Ft/sec. 3)			Est. Angle of Impact		Erosion Index See Footnote (4)			
	COM		CWM		COM		CWM		Fuel Only	Emulsion				AIR		STEAM	
	Air	Steam	Air	Steam	Air	Steam	Air	Steam		Air	Steam	Fuel	Emul.	COM	CWM	COM	CWM
A					¢	¢	¢	¢									
3		0.25				0.163			11	N.A.	N.A.	180°		11			
Rating #	3	5	0	0	3	6½	0	0	0	0	0	6	0	5		5	
11			0.4				0.8		3.85	N.A.	N.A.	180°		3.85		N.A.	
Rating #	3	0	6	0	3	0	6	0	0	0	0	0		9½(cwm)		0	
20(c)	0.365	0.24	0	0	0.073	0.163	0	0	6.85	N.A.	N.A.	180°		6.85		0	
Rating #	5	5	3	3	5	6½	3	0	0	0	0	0		8½		5	
16									6.6	N.A.	N.A.					7.47	
Rating #	0	0	0	0	0	0	0	0	0	0	0	60°		5		8	
28	0.175	0.135			0.035	0.088			< 1			30°		< 3		< 3	
Rating #	4	6	0	0	4½	7½	0	0	8	0	0	0		8½		8½	
B																	
2	0.20				0.04				0.8	7	0		45°	8.4		N.A.	
Rating #	9	0	0	0	9	0	0	0	0	0	0		0	7		5	
19			0.25				0.05		N.A.	380	0		45°	8		0	
Rating #	3	0	8	0	3	0	8	0	0	0	0	0	0	3	8	3	5
25-26	0.25	0.21			0.05	0.137			71		269		45°			3.01	
Rating #	0	0	0	0	8	8	0	3	0	0	0	0	0	8	5	9½	8
21	0.12				.024					103.6			45°	7.06			
Rating #	9½	0	5	0	9½	5	5	0	0	0	0	0	0	8½		0	

TABLE . Page 3
ATOMIZER ASSESSMENT INDEX

Life Atom., Fuel Cons. & Cost; combustion eff.;size coal particle dispersion; actual %O_2; % carbon burn-out;
N.A. = Not applicable Data from Tables 1 - 1A - 1B as of approx. Oct. 1980

Atom. Mode and Sect. No.	Combustion Efficiency				Air/Steam Atom. Capability				Burming Experience		No. of Points	
	% O_2		% Burn Out		COM		CWM					
	COM	CWM	COM	CWM	Air	Steam	Air	Steam	Com	Cwm	Com	Cwm
A												
3					0	5	0	3			46½	10
Rating #		5		5				(x)	0	0		
11		3.75		90			x					
Rating #	3	8	5	9	3	0	5	0			30	58½
20(c)					x	x						
Rating #	5	5	5	5	5	5	3	3	0	0	72	61½
16		3.5	95						x	0		
Rating #	8½	7	9½	7	5	0	3	0	9½	0	75	46½
28	5		98		x	x					69	14
Rating #	7	5	9	3	3	3	0	0	0	0		0
B												
2				90	x							
Rating #	5	5	9	5	5	0	3	0	8	3	62	29
19		3					x			x		
Rating #	7	9	5	3	3	0	5	0	0	9½	42	76
25-26		3		95		x			x			
Rating #	9	7	9½	8	3	5	3	5	9½	0	91	54
21					5	0	3	0				
Rating #	5	3	5	3	5	0	3	0	7	0	72	34

TABLE B-1 Page 1.1
ATOMIZER ASSESSMENT INDEX

Life Atom., Fuel Cons. & Cost; combustion eff.;size coal particle dispersion; actual %O_2; % carbon burn-out;
N.A. = Not applicable Data from Tables 1 - 1A - 1B as of approx. Oct. 1980

Section No.	Atomizing Mode	Related Fig. Nos.	Manufacturers Known Atomizer Life, Hrs.						Manufacturers Estimate of Possible Atom. Life, Hrs.						Operating Experience		Particle Size M.D., uM	
			Tool Steel		Alloy		Ceramic		Tool Steel		Alloy		Ceramic					
			com	cwm	com	cwm	com	cwm	com	cwm	com	cwm	com	cwm	com	cwm	com	cwm
1	C 1) C-Special Internal Em.	1		300								600			x	x		
Rating #			5	8	5	5	5	5	0	0	5	7½	5	5	5	9	0	0
7	C-Cavity Internal Em.	4																
Rating #			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20(a)	C-Cavity Internal Em.	13																
Rating #			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20(b)	C'Tip Em.												2000					
Rating #		14.1	0	0	0	0	0	0	0	0	0	0	5	3	0	0	0	0
8	C'Tip Em.	5			6.0 (Trial)						400							
Rating #			0	0	5	3	0	0	0	0	5	0	0	0	0	0	0	0
17	C'Tip Em.	28(1)	450								>1000				x			
Rating #			8	3	0	0	0	0	0	0	5	3	0	0	9	0	0	0
29	C'Tip Em.	25													x	x		100uM
Rating #					5	5	5	5	0	0	0	0	0	0	5	8½	5	9½

EM = Emulsion

1) Modified by Dudley-Higgins of Florida Power Corporation, with removable inserts.
(modifications not shown in Figure 28)

TABLE B-1 Page 1.2
ATOMIZER ASSESSMENT INDEX

Life Atom., Fuel Cons. & Cost; combustion eff.;size coal particle dispersion; actual %O_2; % carbon burn-out;
N.A. = Not applicable Data from Tables 1 - 1A - 1B as of approx. Oct. 1980

	Atom. Fluid Cons. Lb/Lb fuel				Cost Atom. Fluid/Lb Fuel				Exit Velocities Ft/sec.			Est. Angle of Impact		Erosion Index See Footnote 4)			
	COM		CWM		COM		CWM		Fuel Only	Emulsion				Air		Steam	
	Air	Steam	Air	Steam	Air	Steam	Air	Steam		Air	Steam	Fuel	Emul.	COM	CWM	COM	CWM
					¢	¢	¢	¢									
1 Rating #	0	5	5	.125 9½	0	5	5	.082 9½	0	0	5 0	0	30° 0	5	5	8½	7 8½
7 Rating #	0.35 7	0.30 7	3	3	0.7 5	0.196 5	3	3	0	0	650 0	0	30° 0	7	3	6.6 8½	3
20(a) Rating #	0.81 3	0.48 3	3	3	0.16 3	0.31 3	3	3	0	410 0	541 0	0	30° 0	4.70 9½	3	4.71 9½	3
20(b) Rating #	0.23 8½	0.15 9½	3	3	0.46 8½	0.098 9½	3	3	0	0	404 0	0	30° 0	5	3	8.6 7	3
8 Rating#	0.15 9½	0.15 9½	0	0	.03 9½	0.098 9½	3	3	0	0	0	0	0	0	0	0	0
17 Rating #	0	0.12-0.16 9½	0	0	0	0.078 9½	0	0	0	0	537 0	0	35° 0	0	0	9 8½	8.5 3
29 Rating #	3	3	.11 9½	3	5	3	.022 9½	3	NA 0	898 0			30° 0	3	18 5	3	5

TABLE B-1 Page 1.3
ATOMIZER ASSESSMENT INDEX

Life Atom., Fuel Cons. & Cost; combustion eff.;size coal particle dispersion; actual %O_2; % carbon burn-out;
N.A. = Not applicable Data from Tables 1 - 1A - 1B as of approx. Oct. 1980

Atom. Mode and Sect. No.	Combustion Efficiency				Air/Steam Atom. Capability				Burming Experience		No. of Points	
	% O_2		% Burn Out		COM		CWM					
	COM	CWM	COM	CWM	Air	Steam	Air	Steam	Com	Cwm	Com	Cwm
1 Rating #	5	5	8½	90 8½	0	5	x 5	x 9½	5	x 9	82	114
7 Rating #	0		0		5	5	0	0	0	0	49½	24
20(a) Rating #	0		0		5	5	3	3	0	0	41	24
20(b) Rating #	0		0		3	5	0	0	5	3	59	24
8 Rating#	0		0		0	5	0	0	5	0	24	0
17 Rating #	1 9	3	99 9	3	0	x 9½	0	0	x 0	0	86	15
29 Rating #	3	5-6 8	98 5	99 9	3	3	x 5	x 5	3	x 8	57	98

1) on Carbogel CWM

TABLE B.2
CLM ATOMIZER
RATING TABULATION

CATEGORY	EMPIRIC STATUS	POINTS RATING
Cost of Atomizing fluids lb./lb. fuel	Steam .10¢ to .20¢	9½-5
	Air .02¢ to .06¢	9½-5
Erosion Index		
	5	9½
	6	9
	7	8½
	8	8
	8	5-7
Combustion Efficiency % O_2	2	9½
	3	9
	4	8½
	5	7
Combustion Efficiency % Carbon Burn-Out	.90 to .99	9-9½
	.85 to .90	7½-8½
	.80 to .85	7-8½
	.75 to .80	5-7
	.75	0
Capability of both air & steam atom.	COM	5
	CWM	5
	Judgment based on design	
	COM	3
	CWM	3
	No opinion	0

TABLE B.2
CLM ATOMIZER
RATING TABULATION

CATEGORY	EMPIRIC STATUS	POINTS RATING
Lifehours	Known	
Present	Tool Steel	5-7
	Alloy)	5-9½
	Ceramic)	
	Unknown	
	Judged from design	3-5
	No opinion	0
Atomizing Eff.		
Atomized particle mean dia, uM	80-100 Mu	9½
	Judged from design	5
	No opinion	0
Atom. Fluid Cons. lbs./lb. fuel		
Steam	.10 to .25	9½-5
Air	.15 to .30	9½-5
Operating Hours (before need of change)		
	Actual experience	5-9½
	Mfr's judgement of future development	3-7½
	No opinion on increased life	0

TABLE B.2.1

RANK ORDER

Rank	No. of Pts.	Sect. No.	Rank	No. of Pts.	Sect No.
	CWM			COM	
WITH OPERATING EXPERIENCE					
1	114	1	1	91	25-26
2	98	29	2	86	17
3	76	19	3	82	1
4	54	25-26	4	75	16
5	46½	16	5	72	21
6	34	21	6	57	29
			7	62	2
			8	42	19
NO OPERATING EXPERIENCE					
1	61½	20(c)	1	72	20(c)
2	29	2	2	69	28
3	24	7-20(a)-20(b)	3	59	20(b)
4	18	8	4	49½	7
5	15	17	5	46½	3
6	14	28	6	41	20(a)
7	10	3	7	24	8

TABLE C

Coal-Water-Mix Atomizers Life

Duration in hours versus change frequency required

L.F. - .55 (or approx. 5000 Hrs./yr.

Atomizer life hours	Freq. of change/ yr.	Weekly change freq. weeks
200	25	2
300	17	3
500	10	5
750	7	7
1,000	5	10
2,000	2½	20

Foot Notes to Tables B & B.1

1. Atomizing Modes:

A External	Atomizing fluid and fuel combine outside of a confining port of passage.
B Hybrid	a) Only a portion of the atomizing fluid combines with the fuel. b) Only a relatively small surface is contacted by the combined atomizing fluid and fuel, during the expansion stage where fuel is atomized.
C Internal	a) Full emulsion where atomizing fluid and fuel mix within a cavity of relatively large volume then exit through single or multi-hole orifices. b) Tip emulsion where atomizing fluid and fuel mix in narrow channels and exit through multi-hole orifices.

2. Cost of atomizing fluid based on fuel energy services only, without considering of capital cost, discount rate, maintenance, depreciation, etc.

3. Where fuel only velocity is given a value, it is based on manufacturer's data and is meaningful only in type A atomizers.

4. The erosion index for class B & C atomizers is based on the assumption that the emulsifying phenomenon, diminishes the erosive impact of the fuel and its ash by the ratio

$$\frac{\text{CWM}}{\text{CWM + Atomizing fluid}} \quad \times \quad \text{Emulsion exit velocity}$$

Plus

the effect of the angle of impact of the emulsion on the exit ports. This impact effect is given the number $\sin^{-1}\theta$ where $\theta$is the angle of impact. The use of $\sin^{-1}$ (inverse sin value) is based on known phenomenon that max. erosive effect occurs at an angle of 30°. Now $\sin 30° = ½$ and therefore $\sin^{-1} 30° = 2$ which is the max. sin value in the range 0°-90° (e.g. $\sin 45° = 1.414$.

5. Atomizing fluid specific consumptions are based on 100% burner operating value, and are based on #6 oil, except where the table data indicates a COM or CWM as the fuel for which the atomizing fluid consumption values are given (i.e. atomizers with COM and/or CWM operating experience, and known flows (e.g. sections 1, 2, 11, 20, 21 & 25.)

General Notes

a) Blank spaces - information not available or not at hand.

b) N.A. - not applicable.

c) E - Estimate by manufacturer or author's judgment based on atomizing design.

d) COM is based on 50/50 mix of coal & oil by weight.

e) CWM is based on a 70/30 mix of coal and water by weight.

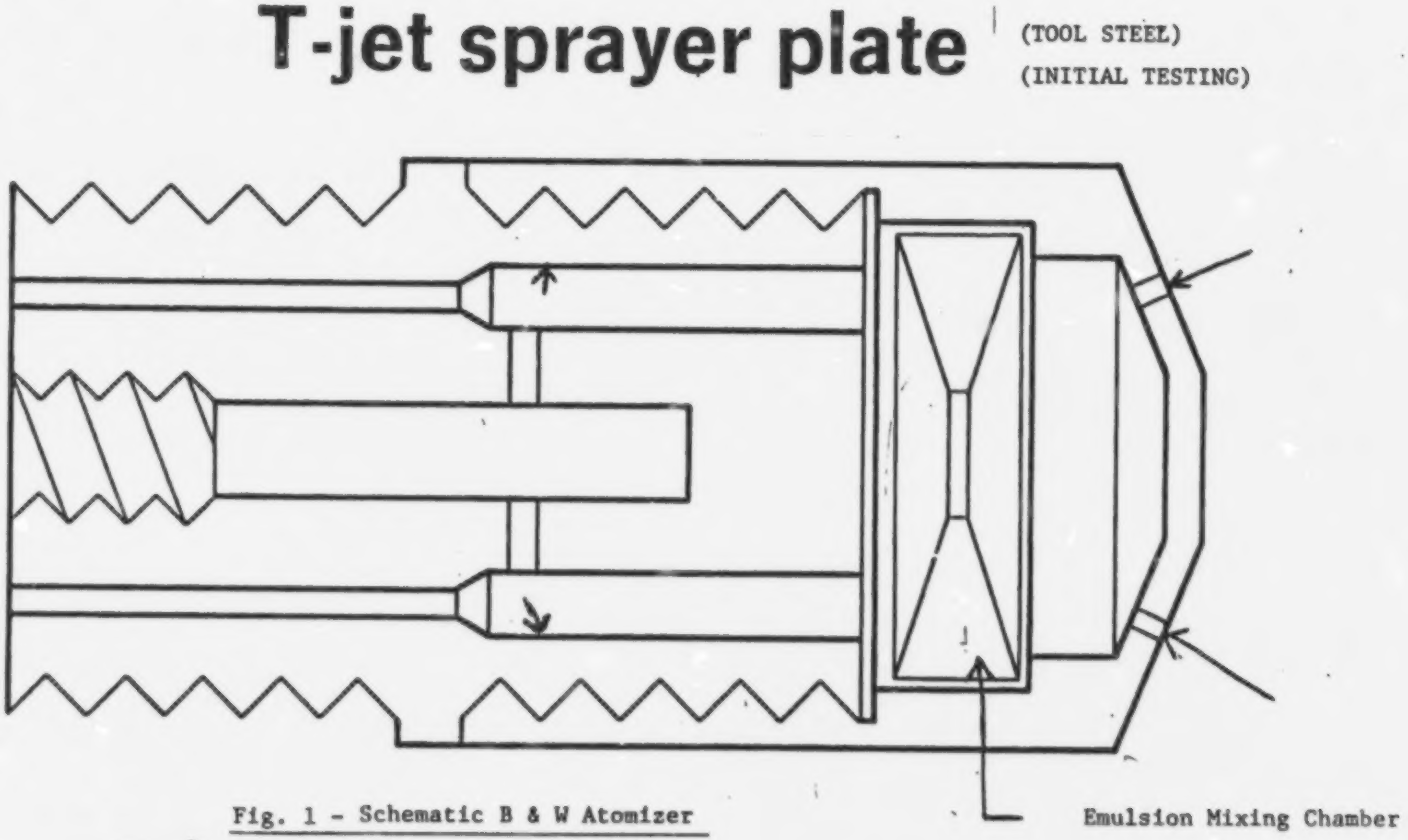

T-jet sprayer plate
(TOOL STEEL)
(INITIAL TESTING)
Emulsion Mixing Chamber

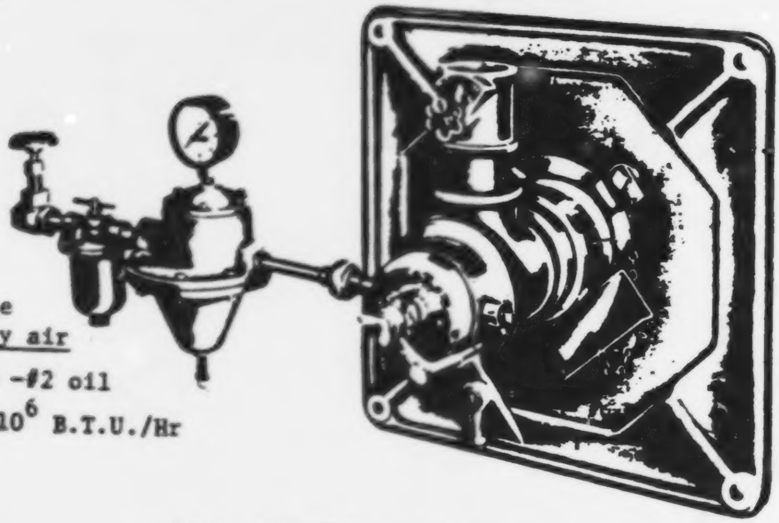
Fig. 1 - Schematic B & W Atomizer

→ = wear points - after 300 hours
(Not enough for rejection)

Combustion by
HAUCK®

FIG.2 - PP.1,2 & 3
BROCHURE MATERIAL
OF HAUCK 780 SERIES

780 SERIES SELF-PROPORTIONING OIL BURNER



Capacity Range
with secondary air
4-200 USgph -#2 oil
$6.5.10^6$-30.10^6 B.T.U./Hr

See page 2 for
cup type nozzle
detail

Fig. 1 – 780P Oil Burner sleeve bracket set, and optional furnace mounting plate.

Maximum capacity cup nozzle:
Size #12 - 500 USgph =
75.10^6 B.T.U./Hr.

The burners in the Hauck 780 Series are self-proportioning, oil fired burners designed for highly efficient operation using low pressure atomizing air. The use of low pressure air results in lowered operating costs since motor driven blowers can be used. These blowers usually operate at about one-quarter the power consumption needed by air compressors for high pressure air atomizing and less than the cost of generating high pressure steam for steam atomizing burners. On multiple furnace applications, a series of smaller blowers can be used in place of a large central blower. Thus smaller and shorter main air piping can be used to decentralize the supplying of atomizing air. Additional savings result from longer uninterrupted operating service and less maintenance. The complete line of Hauck Low Pressure Air Turbo Blowers is described in bulletins GB 139 (direct drive) and GB 149 (belt drive).

EFFICIENT OIL ATOMIZATION

All grades of fuel oil, even the heaviest, are completely atomized to provide the most efficient combustion. This is achieved by controlling the air flow at the nozzle outlet. Constant full primary and secondary atomizing air pressure ire maintained, at all times, right at the point of oil atomizaion. This unique characteristic of the Hauck 780 burner

FEATURES

- ACCURATELY PROPORTIONS OIL AND AIR
- HIGHLY EFFICIENT ATOMIZATION
- SINGLE LEVER CONTROL
- BURNS ALL GRADES OF FUEL OIL
- WIDE TURNDOWN

GB410FF

HAUCK MANUFACTURING CO., P O Box 90 Lebanon Pennsylvania 17042

Copyright © 1977 by Hauck Manufacturing Company

Code
AA1

insures complete atomization from maximum to minimum burner capacity. In contrast, the air flow in most other burners is controlled by a valve located in the air piping ahead of the burner. In this arrangement, constant primary and secondary atomizing air pressure is not always maintained at the burner. The result is a loss in efficiency which wastes fuel and costs you money.

AIR SUPPLY

The required atomizing air pressure at the burner for average applications is 16 oz. for light distillate oils and from 16 to 24 oz. for heavy residual oils. The higher air pressure range may be required for high furnace temperatures or greater oil burning capacities for maximum heat liberation in a specific combustion space. Air supply piping should enter the burner from above. It can enter from either side of the burner body if necessary.

OIL SUPPLY

Oil should be supplied to the burner pressure regulator at 25 psig or more for light oils not requiring heating, and at 35 psig or more for heavy heated grades of oil. The pressure regulator reduces the oil pressure and holds it constant at the required operating pressure, usually 2 to 10 psig at the burner.

Heavy residual oils must be heated to a viscosity of 80-90 SSU. The oil temperature should be held constant to avoid variation in burner firing rates. By piping an oil return line to the connection provided, hot oil can be circulated up to and through the oil control valve in each burner. Consequently, the temperature of the oil at the burner can be easily maintained. The oil does not cool off to cause unequal distribution, poor regulation, or atomization problems. At start-up, the hot oil can even be circulated up to and through the valve with no oil entering the burner. When the oil in the valve reaches the required temperature, the oil valve can be opened to light the burner easily.

ECONOMICAL TO OPERATE

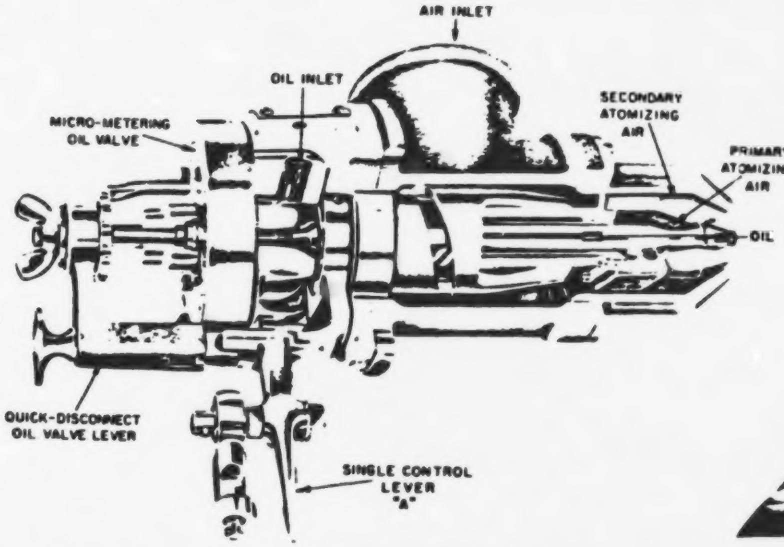
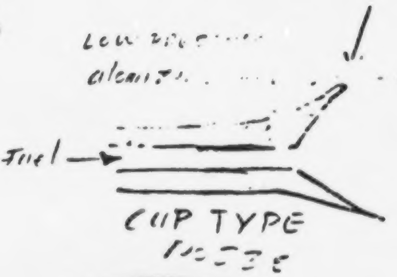


Fig. 2 – Sectional view of a Hauck Self-Proportioning Oil Burner.



OPERATION

All Hauck self-proportioning oil burners are engineered for single, efficient operation. All atomizing air enters the burner at a simple inlet connection, as shown in Figure 2. The oil and air are controlled simultaneously by the single control lever ("A"). Thus the application of this burner to any heat processing equipment immediately eliminates many difficulties encountered with complicated heating equipment which requires frequent manipulation of valves and controls.

Specifically, the primary atomizing air enters the inner air nozzle (B) through tangential openings (C) that give the air a whirling, rotary motion. As the air approaches the space around the oil nozzle with maximum velocity, it strikes and atomizes the oil coming from the oil orifices (D).

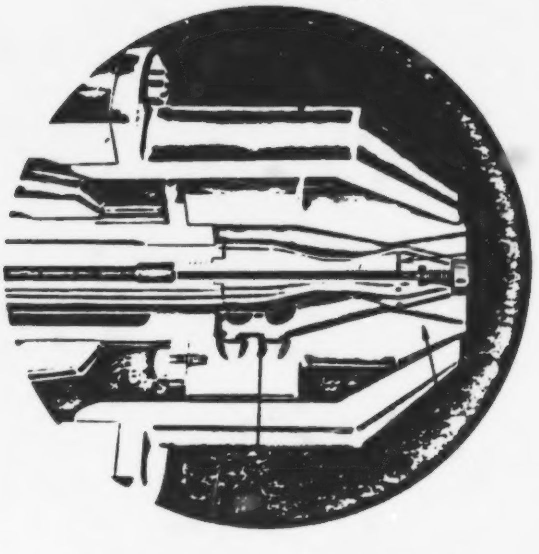


Fig. 3 – Magnified view of nozzle section.

As the resulting air-oil mixture leaves the inner air nozzle in a diverging cone, it is hit by the secondary atomizing air coming from the outer air nozzle opening (F) in a converging cone. This impact further atomizes the oil, producing a foglike mixture of oil and air that is quickly and easily burned with better combustion and no smoke or carbon formation.

The inner and outer air nozzles form a double cone air valve, giving straight line flow air discharge (see Figure 4). Moving the air-oil control lever ("A") toward its high capacity position causes the inner air nozzle (B) to move back from the stationary outer air nozzle (E) ,thus simultaneously and uniformly increasing the air discharge areas of both nozzles and the micrometering oil valve orifice. To increase the air discharge and oil valve orifice areas, the control lever is simply moved to a lower capacity. The butterfly air shutoff valve is used only for starting and stopping the burner, and is wide open whenever the burner is firing. Full atomizing air pressure is always maintained inside the burner throughout the entire range of capacity. All burners on one furnace can be regulated at once by coupling their levers together for manual or automatic firing control.

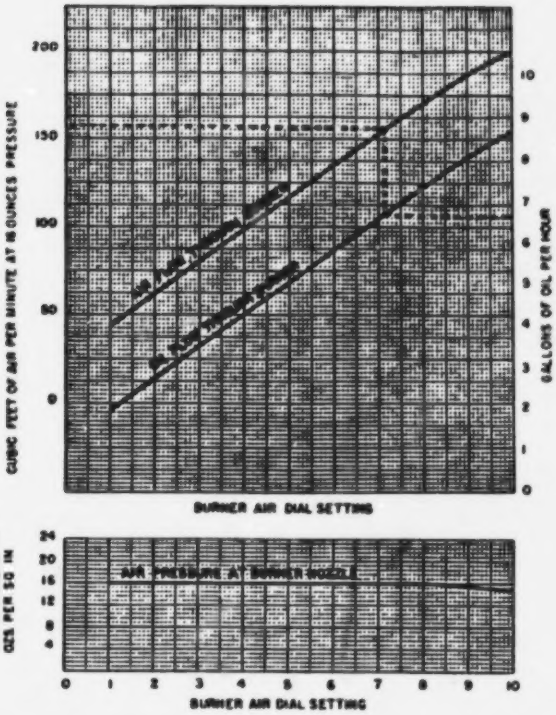


Fig. 4 – Actual straight line proportioning of oil and air flow through the Hauck Self-Proportioning Burner, with 100 per cent of combustion air going through the burner. Note constant air pressure maintained throughout entire range.

BURNER CAPACITIES

OPERATING WITH AIR SHUTTERS CLOSED (No air induced around burner)

Burner No.	Inlet Pipe Sizes (inches)		16 oz. Air Pressure			20 oz. Air Pressure			24 oz. Air Pressure			32 oz. Air Pressure		
			Air (cfm)	Oil (gph)		Air (cfm)	Oil (gph)		Air (cfm)	Oil (gph)		Air (cfm)	Oil (gph)	
	Air	Oil	Max.	Max.	Min.	Max.	Max.	Min.	Max.	Max.	Min.	Max.	Max.	Min.
779	1	3/8	34	1.5	0.75	38	1.7	0.75	42	1.8	0.75	48	2.1	0.75
780	1½	3/8	66	2.9	1.0	74	3.3	1.0	81	3.6	1.0	93	4.1	1.1
781	2	3/8	123	5.4	1.1	138	6.0	1.2	151	6.6	1.3	173	7.6	1.5
782	3	3/8	210	9.2	1.1	235	10.3	1.3	257	11.3	1.4	296	13.0	1.6
783	4	3/8	298	13.0	3.1	334	14.7	3.5	365	16.0	3.9	420	18.5	4.4
784	6	1/2	660	29.0	6.2	739	32.5	6.9	809	35.6	7.6	931	40.9	8.7
785	6	1/2	910	40.0	11.1	1019	44.8	12.4	1115	49.0	13.6	1283	56.4	15.6
786	8	1/2	1620	71.0	16.7	1814	79.7	18.7	1985	87.3	20.5	2284	100.4	23.6

- STeel

OPERATING WITH AIR SHUTTERS OPEN (With induced secondary air)

Burner No.	Inlet Pipe Sizes (inches)		16 oz. Air Pressure			20 oz. Air Pressure			24 oz. Air Pressure			32 oz. Air Pressure		
			Air (cfm)	Oil (gph)		Air (cfm)	Oil (gph)		Air (cfm)	Oil (gph)		Air (cfm)	Oil (gph)	
	Air	Oil	Max.	Max.	Min.	Max.	Max.	Min.	Max.	Max.	Min.	Max.	Max.	Min.
779	1	3/8	34	2.5	1.3	38	3.1	1.4	42	3.41	1.4	48	4.2	1.5
780	1½	3/8	66	4.9	1.7	74	6.0	1.8	81	6.9	1.9	93	8.2	2.2
781	2	3/8	123	9.2	1.9	138	10.9	2.2	151	12.6	2.5	173	15.2	3.0
782	3	3/8	210	15.6	1.9	235	18.7	2.4	257	21.5	2.6	296	26.0	3.2
783	4	3/8	298	22.0	5.3	334	26.7	6.4	365	30.5	7.4	420	37.0	8.8
784	6	1/2	660	49.2	10.5	739	59.0	12.5	809	67.8	14.5	931	81.8	17.4
785	6	1/2	910	67.8	18.8	1019	81.5	22.5	1115	93.3	25.9	1283	112.8	31.2
786	8	1/2	1620	120.3	28.3	1814	145.0	34.0	1985	166.3	39.0	2284	200.8	47.2

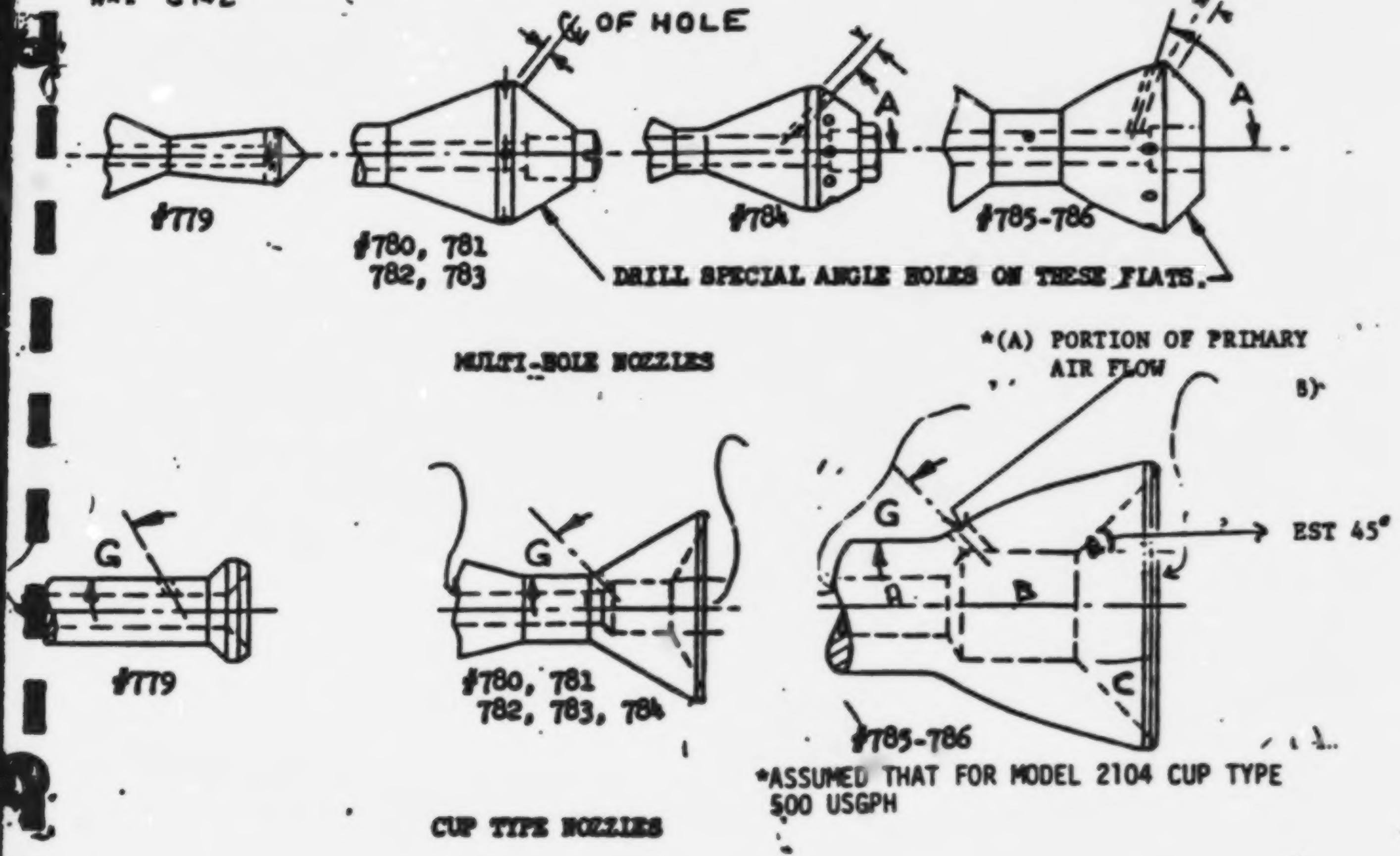
The table above gives approximate burner capacities for combustion chamber drafts from 0.05" to 0.1" water column and with secondary air induced at 41 per cent for 16 oz. pressure, 45 per cent for 20 oz. pressure, 47.5 per cent for 24 oz. pressure and 50 per cent for 32 oz. pressure. With more draft the oil capacity can be increased.

NOTE: Capacities in these tables are for oil of 138,000 Btu per gal. Lighter or heavier oils will vary the capacity according to the Btu content of the oil.

BY J.S. DATE 2/1/61 SUBJECT MULTI-HOLE AND CUP-TYPE OIL NOZZLES FOR SERIES 780 BURNERS SHEET NO. 1 OF

CHKD BY DATE JOB NO. S-142 AB

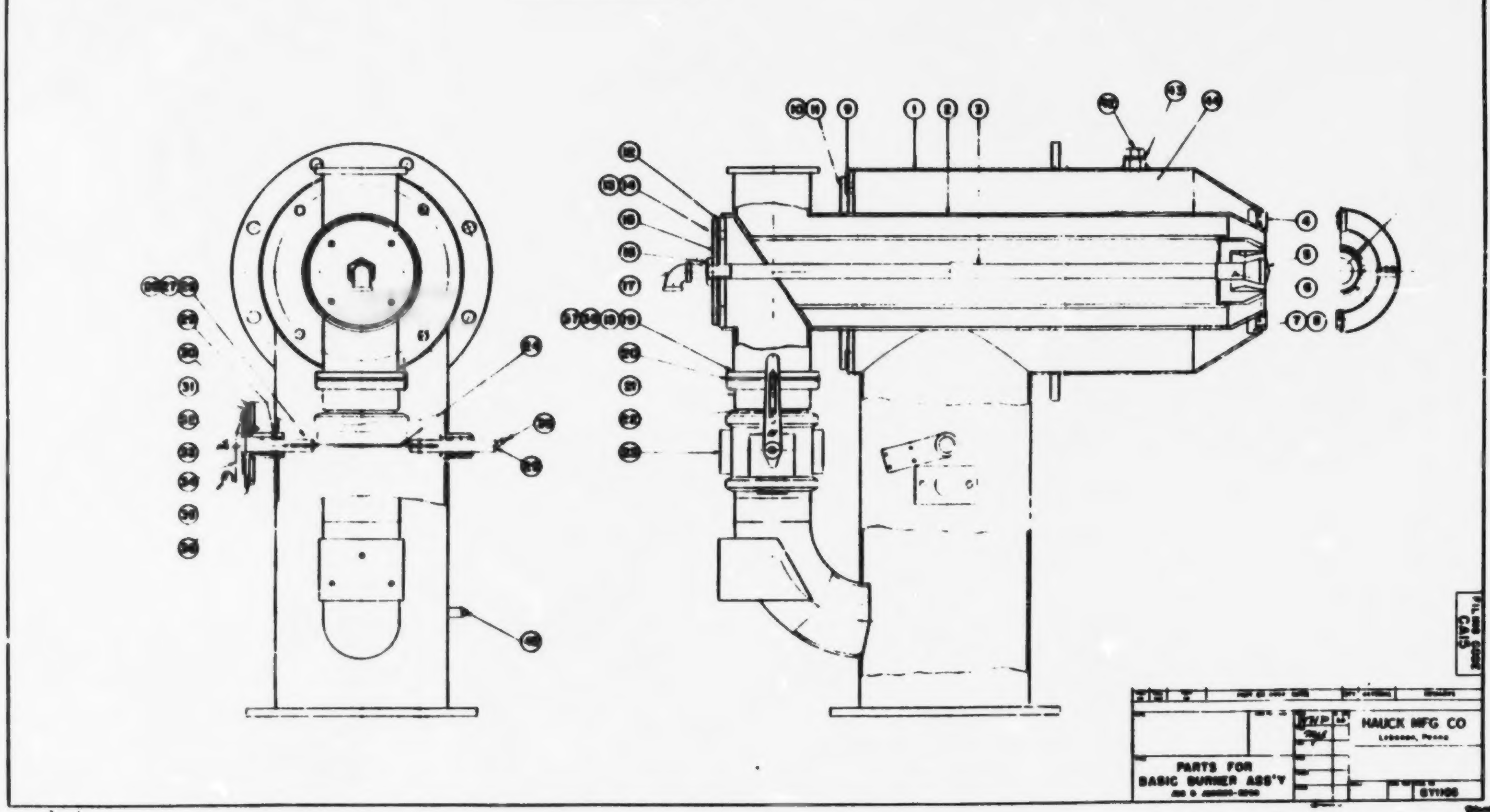
WAS S142


℄ OF HOLE
A
A
#779
#780, 781
782, 783
#784
#785-786
DRILL SPECIAL ANGLE HOLES ON THESE FLATS.
MULTI-HOLE NOZZLES
*(A) PORTION OF PRIMARY AIR FLOW
B)
G
G
G
A
B
C
EST 45°
#779
#780, 781
782, 783, 784
#785-786
CUP TYPE NOZZLES

*ASSUMED THAT FOR MODEL 2104 CUP TYPE 500 USGPH

Fig. 2.1 Hauck Cup Atomizer

FIG. 2.2
DETAILS HAUCK JET BURNER


1
2
3
4
5
6
7
8
9
17
31
FILING CODE
CA15
HAUCK MFG CO
Lebanon, Penna
PARTS FOR
BASIC BURNER ASS'Y

JUL 8 1982

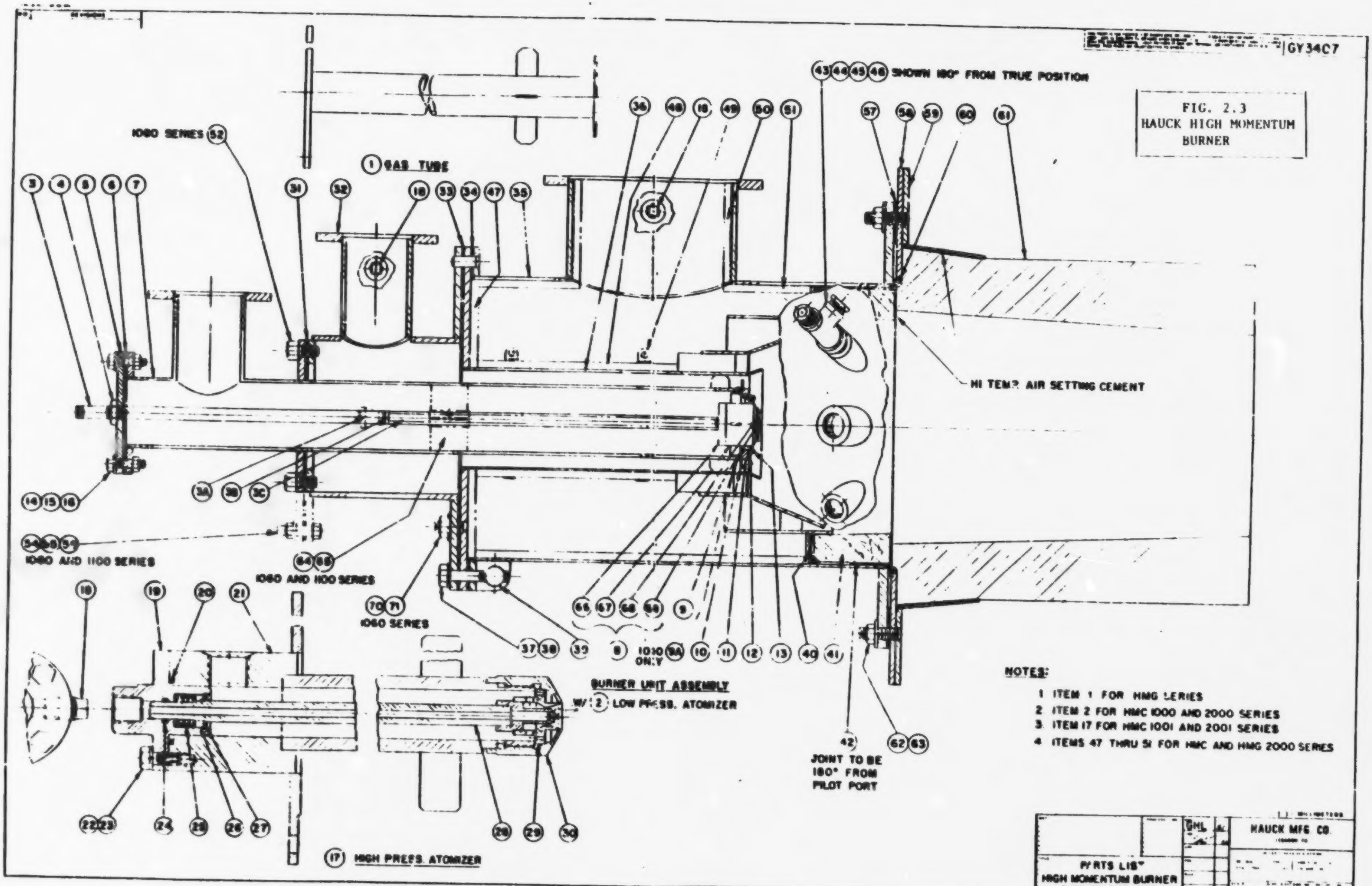


FIG. 2.3
HAUCK HIGH MOMENTUM
BURNER

NOTES:
1 ITEM 1 FOR HMG SERIES
2 ITEM 2 FOR HMC 1000 AND 2000 SERIES
3 ITEM 17 FOR HMC 1001 AND 2001 SERIES
4 ITEMS 47 THRU 51 FOR HMC AND HMG 2000 SERIES

GY34C7
43 44 45 46 SHOWN 180° FROM TRUE POSITION
1060 SERIES 52
1 GAS TUBE
3 4 5 6 7
31 32 18 33 34 47 35
36 48 16 49 50 51
57 58 59 60 61
HI TEMP. AIR SETTING CEMENT
3A 3B 3C
14 15 16
54 55 53
1060 AND 1100 SERIES
64 65
1060 AND 1100 SERIES
70 71
1060 SERIES
37 38 39
66 67 68 69 9
8 1030 ONLY 9A 10 11 12 13 40 41
42
JOINT TO BE 180° FROM PILOT PORT
62 63
BURNER UNIT ASSEMBLY
W/ 2 LOW PRESS. ATOMIZER
18 19 20 21
22 23 24 25 26 27
28 29 30
17 HIGH PRESS. ATOMIZER
PARTS LIST
HIGH MOMENTUM BURNER
(HMC, HMG 1050-2100)
HAUCK MFG CO.
GY3407

vided the oil flow rate has already been controlled at a valve or individual trimming cock. Multiple burners should not be used without individual pressure orifices or trimming cocks on every burner.

1:5 For atomization, almost any clean and dry gaseous fluid can be used at pressures from 5 to 150 p.s.i.g., depending on availability. Atomizing rates will vary from below 0.2 lb/lb. oil to above 0.8 lb/lb. oil...depending on type of fuel, kinetic energy of atomizing fluid, furnace environment, whether application requires fast or slow burning, etc., etc. As a general guide, allow between 5 and 8 ft^3/lb. of compressed air at 10 to 15 p.s.i.g....using the lower rate for the "easy" applications, and approach the higher for the more difficult applications. The smallest 01 and 02 burner sizes are normally used at around 5 or 6 p.s.i.g., or even less pressure for the very lowest rates.

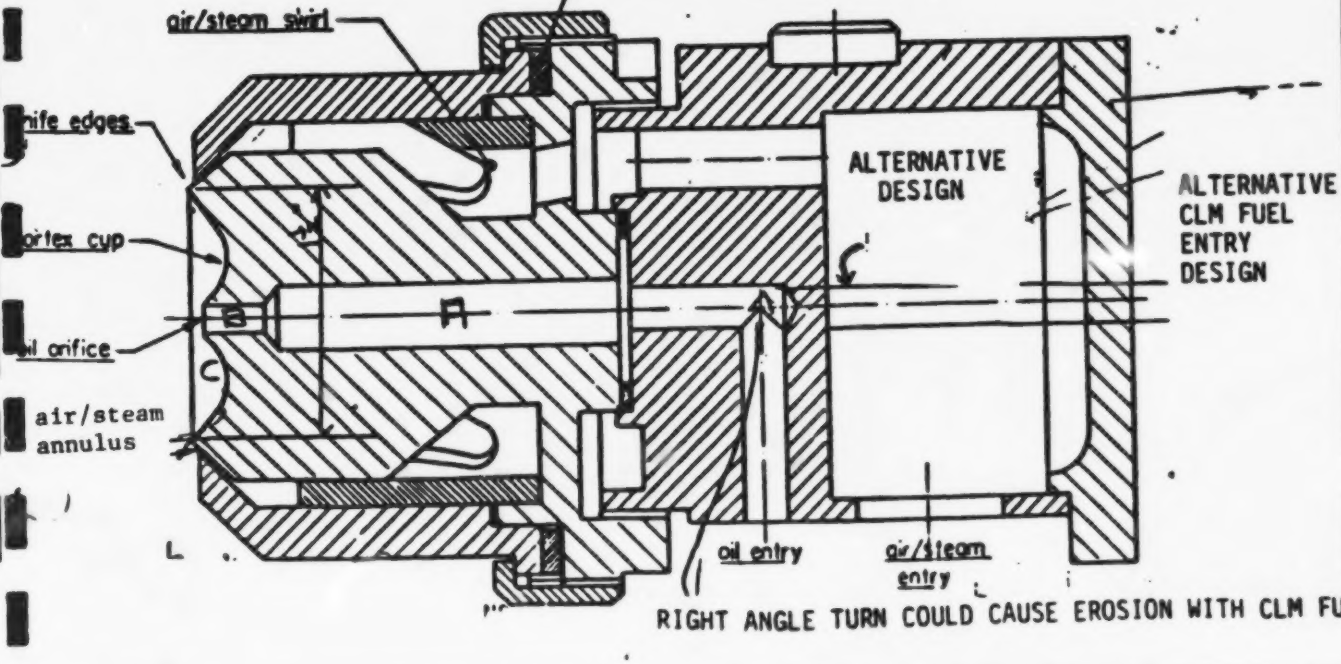
The following gasses have been used successfully as atomizing fluids: compressed air; steam; carbon dioxide; refinery gas; and L.P.G. Oxygen should not be used, since its use will generate extremely high temperatures (circa 3000° C.!). When calculating combustion air quantities, an extra air allowance must be made for exothermic gasses; but with compressed air, the relative amount of combustion air added is less than 5% of stoichiometric, and it is small enough to neglect in most cases.

1:6 Turndown will depend more on the application and control system than the atomizer itself, but it is unlikely to be required at less than 2:1, or more than 5:1. The main factors affecting turndown are fuel rate, type of fuel, hot or cold environment, design of combustor, air register or quarl system, shim setting, excess air quantity, whether atomizing fluid supply is modulated, etc., etc.

1:7 Illustration of Mk I atomizer:

FIG.3
SCHEMATIC URQUHART VORTEX CUP ATOMIZER

MODEL CODE NO. "SFF"



RIGHT ANGLE TURN COULD CAUSE EROSION WITH CLM FUELS

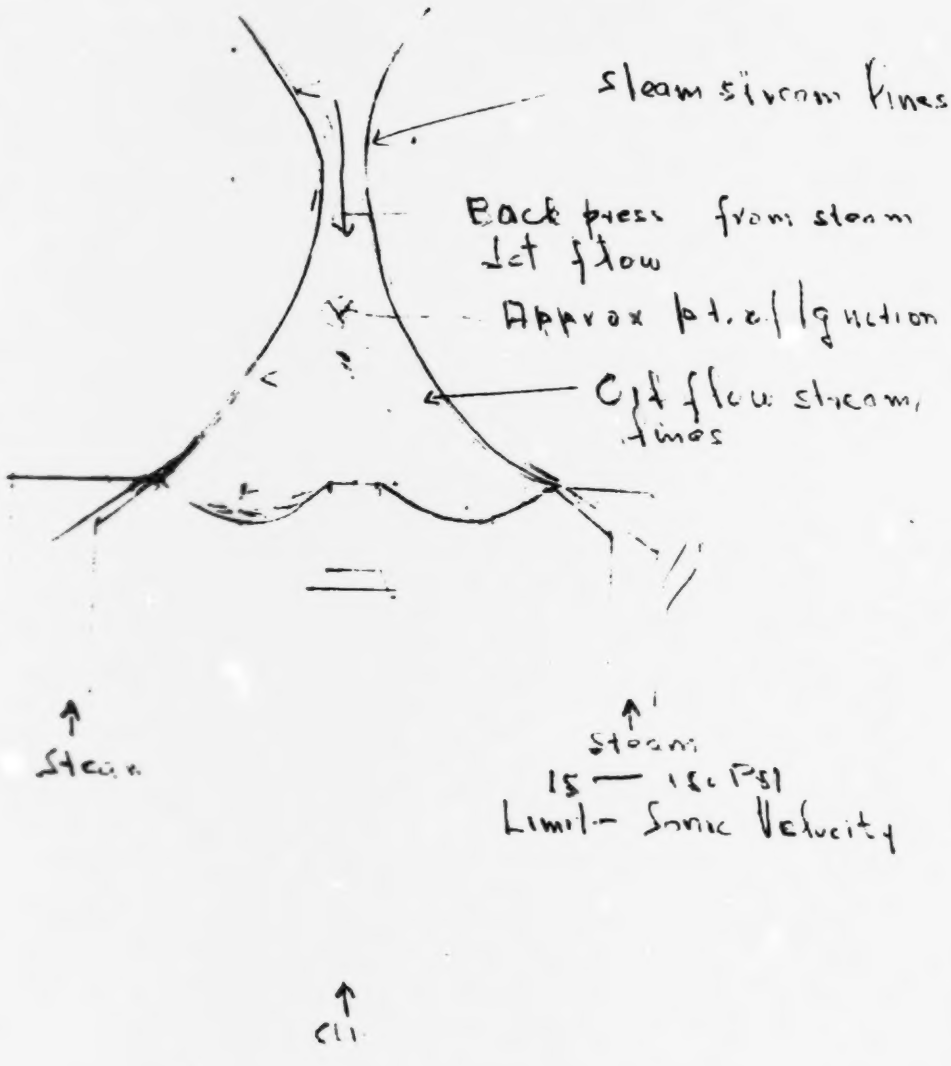

Steam stream lines
Back press from steam jet flow
Approx pt. of Ignition
Oil flow stream lines
Steam
Steam
15 — 150 PSI
Limit – Sonic Velocity
Oil

FIG 3.1 Atomizing Function of [illegible] SFF Atomizer (Schematic)

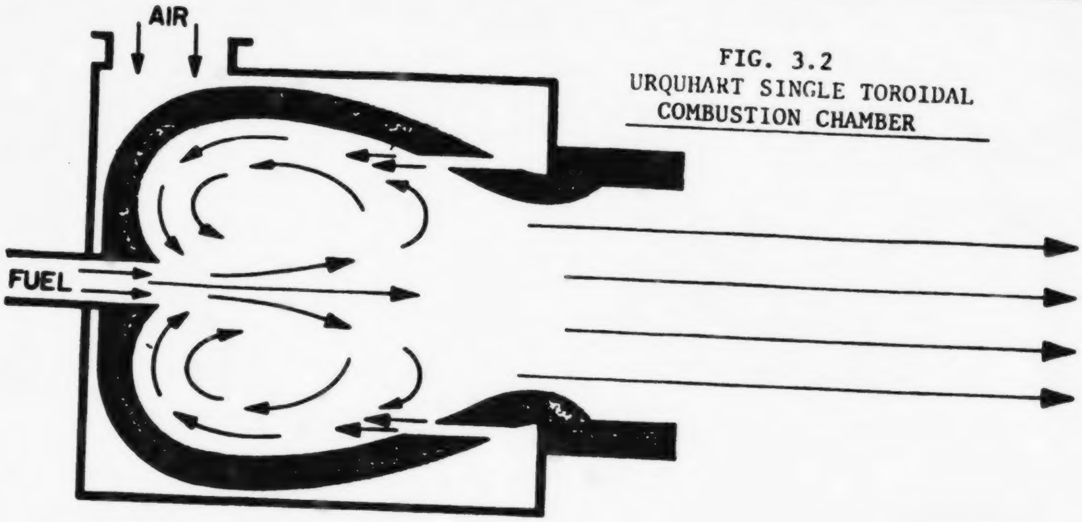


FIG. 3.2
URQUHART SINGLE TOROIDAL
COMBUSTION CHAMBER

SINGLE TOROIDAL COMBUSTION CHAMBER

WHAT THE STCC OFFERS:

Fully controlled small flame at high intensity heat release

Operation down to low excess air ratio

Fuels from Bunker "C" to natural gas, singly or together

Excellent radiant heat transfer characteristics

Very large turndown capability

Low noise and pollution levels

High efficiency with minimal power consumption

Long life, industrially proven reliability

WHY THE STCC WORKS:

Fine atomization of liquid fuels by powerful bifluid oil burner

Intimate mixing of fuel and air with persistent toroidal vortex

High air and fuel preheat in radiant refractory lined precombustor

Stable flame front from perfectly matched kinetics

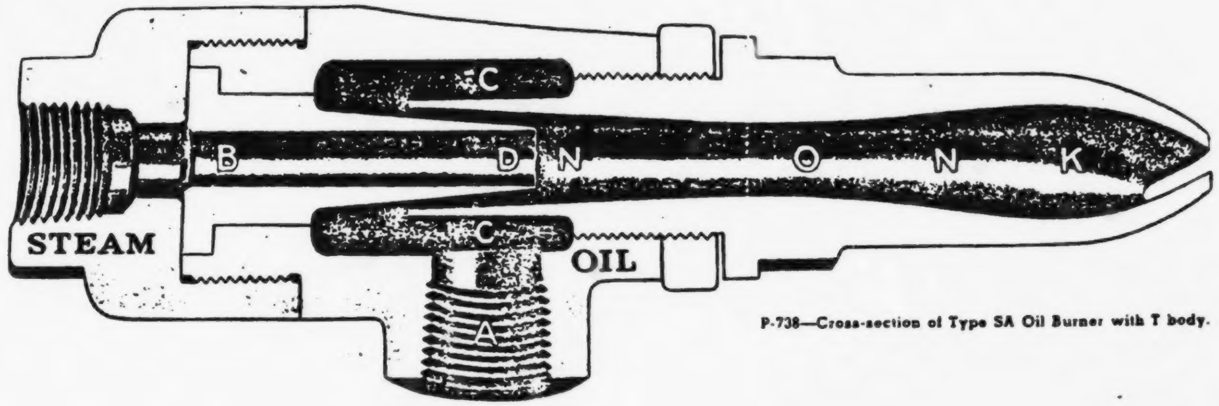
P.T.O

FIG. 4(Brochure Figs. 738-9,P.2)
N.A.O. STEAM ATOMIZING NOZZLE
GENERAL ARRANGEMENT

STEAM ATOMIZING OIL BURNERS

AND AUXILIARY EQUIPMENT

Type SA



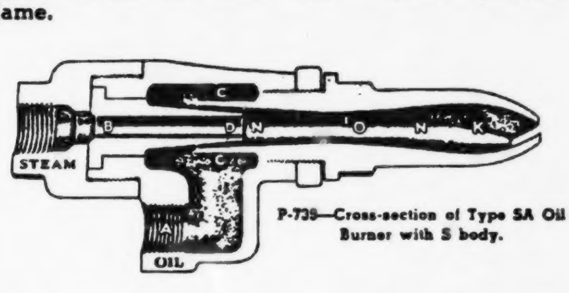
P-738—Cross-section of Type SA Oil Burner with T body.

THIS BULLETIN refers to our Type SA Oil Burners, using either steam or compressed air for atomizing the oil. With this burner the very lowest and cheapest grades of oil or tar can be completely atomized and efficiently burned.

In boiler operation the consumption of steam for atomizing the oil will vary from .8% to 1.2% of the steam generated. This corresponds to .10 lb. to .15 lb. of steam per pound of fuel. The low oil pressure (50 to 60 lbs.) and low oil temperature required assure an extremely low total steam consumption for pumping, heating and atomizing the oil.

The burner is of the internal atomizing type, having two chambers inside the burner into the first of which oil and steam are fed through separate channels, in which chamber the oil and steam are mixed. The oil mixture then passes into the second chamber where it is emulsified before being fed into the furnace.

Oil under low pressure enters the burner at (A) and passes into a chamber (C), which entirely surrounds the steam nozzle (BD). The steam nozzle (BD) extends into and discharges the steam into a forward nozzle (NON). The oil passes from chamber (C) in an annular film into the same nozzle (NON). This nozzle (NON) forms a venturi tube with its throat at (O), at which point the steam cuts its way through and mixes with the oil. The oil and steam so mixed then pass to the front chamber (K), where they are churned into an emulsion, while the discharge orifice (the tip of the burner) through which the oil is fed from chamber (K) into the furnace is designed to sufficiently retard the discharge of the mixture of oil and steam during the churning process. The mixture lights readily and burns with a mellow, gaseous flame.

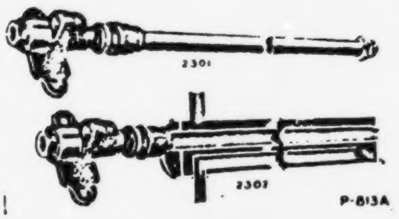


P-739—Cross-section of Type SA Oil Burner with S body.

The burner will operate continuously without clogging and without need of cleaning, and will consume every atom of the heaviest fuel. It will operate equally well at any point between its minimum and maximum capacity, and will hold with absolute precision any flame regulation required. When used with our indicating control valves for regulating the

After thirty-seven years experience in the manufacture and application of all types of oil burners we are still firmly convinced that, except for a few isolated special applications, our internal mixing steam atomizing oil burner applied to a properly designed furnace will burn heavy oil more completely, more steadily, more uniformly—with lower maintenance costs for equipment and furnace—be less affected by changing factors such as draft, grade of oil, etc.—require less attention from firemen—and give greater economy and more reliable and overall satisfactory service than any other oil burner.

FIG.4.1
PRESS./CAP. TABLE

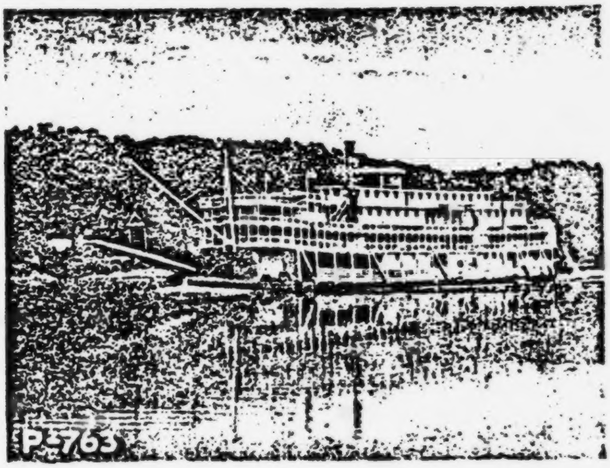


P-813A—The Type SA. Model OH Oil Burner provides the ideal flame for firing open hearth furnaces with any grade of fuel oil or tar, using saturated or superheated steam, or compressed air for atomization. This burner is specially suited for operation with the new oxygen system of flame support. As in the standard Type SA Burner, it incorporates the venturi throat and internal mixing chamber, permitting a wide range in capacity and velocity of the mixture. The upper view shows this burner with dry tube and stainless steel tip; lower view shows same burner fitted with water cooled jacket. All sizes are fitted with mounting pad.

Available in 3 sizes with capacities as follows:

CAPACITIES, GALLONS PER HOUR

BURNER NO.	OIL PRESSURE AT CONTROL STAND LBS./SQ. IN.		
	80 lbs.	100 lbs.	110 lbs.
2	250 gals.	300 gals.	350 gals.
3	375 gals.	475 gals.	525 gals.
4	475 gals.	575 gals.	625 gals.
5	575 gals.	675 gals.	725 gals.



P-763—Steamer Gordon C. Greene of the Greene Lines. Cincinnati, Ohio, one of the two remaining Mississippi River packets made famous by Mark Twain, and later by Will Rogers in his picture "Steamboat Round the Bend." Unlike the early models which were fired with wood, then coal, the Gordon C. Greene has a modern steam generating plant, using heavy fuel oil fired with National Airoil Type SA Oil Burners.

REFUSE OIL BURNERS

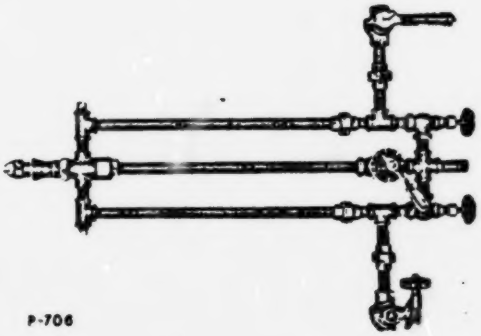
Type SA — Model D

Petroleum refineries, chemical and industrial plants frequently have available as part fuel or for disposal, a quantity of liquid or semi-liquid material that is so low in heat value that difficulty is experienced in burning it.

These materials diluted with water or otherwise may be

ACID OR CAUSTIC OILS OR SLUDGES
ASPHALTS FROM VACUUM DISTILLATION
STORAGE TANK BOTTOMS OR PRECIPITATION
SETTLING POND SKIMMINGS OR SLOPS
POLYMER OILS
HEAVY PETROLATUM
VEGETABLE OR ANIMAL OIL RESIDUUM
ENGINE AND MACHINE OIL DRAININGS
WASTE CUTTING OILS
SULPHITE PULP LIQUORS

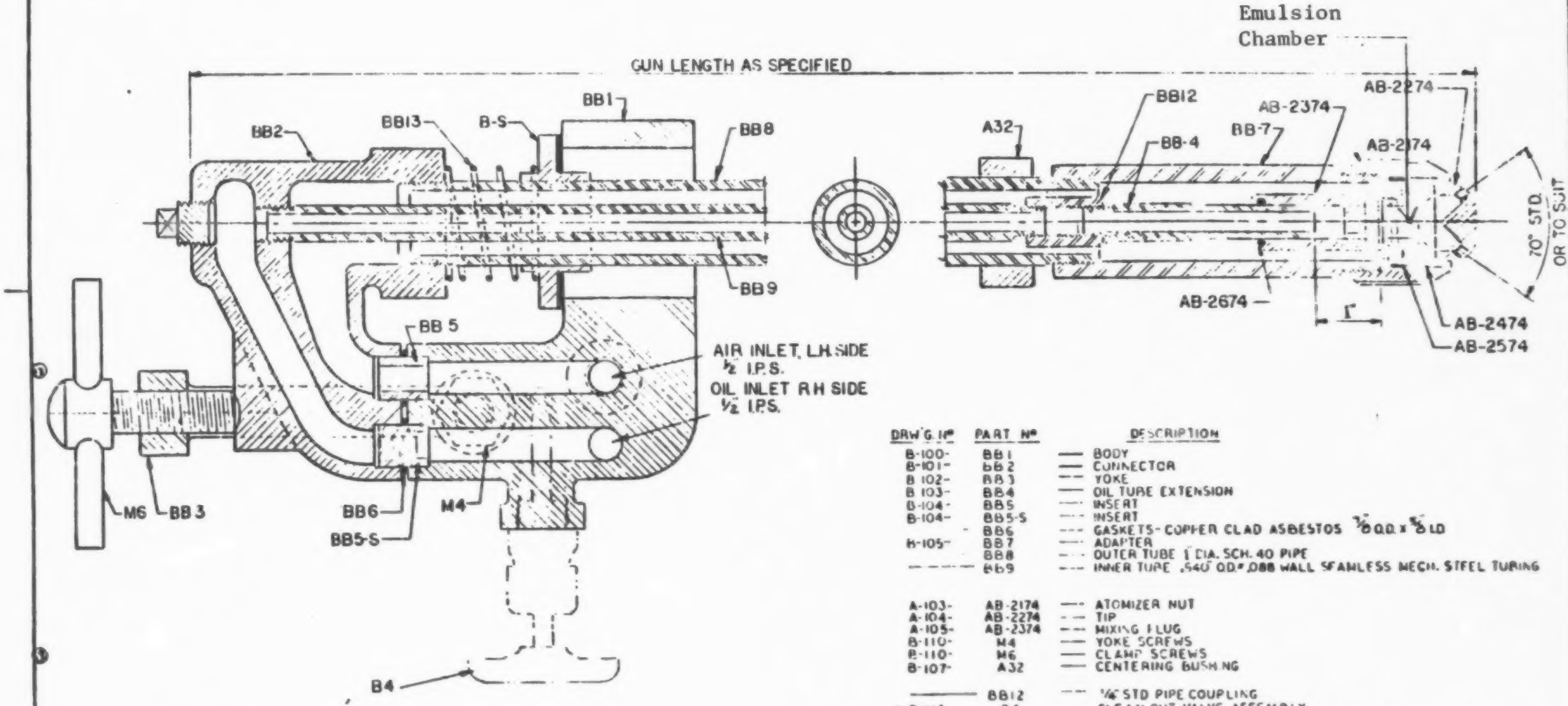
Unless completely consumed the furnace emits obnoxious fumes and stack solids that frequently cause neighborhood complaints. Trouble may be experienced also in maintaining ignition, even with the closest attention, as a result of which the furnace tends to fill up with partially burned material.



Our Type SA, Model D (Steam Atomizing Duplex) Oil Burner has been highly satisfactory for burning this material in suspension. This burner will insure stability of ignition of the refuse fuel because it is designed to burn a small portion of regular fuel oil with the refuse fuel. This proportion may be one part regular fuel oil to three parts refuse oil, although in some cases no regular fuel oil is needed after the furnace has become well heated. Mixing of the refuse oil with fuel oil is done within the venturi throat and mixing chamber of the burner. The Type SA, Model D Oil Burner will also function entirely on fuel oil in those plants where the supply of refuse oil is intermittent.

The Type SA, Model D Oil Burner is made in sizes No. 1, No. 2 and No. 3, with rated capacities of 40, 80 and 120 gallons per hour respectively of fuel oil or mixture of fuel oil and refuse. These capacities are predicated on 60 pounds liquid pressure and 70 pounds atomizing steam or air pressure.

FIGURE 5
GENERAL ARRANGEMENT BURNER
GUN WITH ATOMIZER


Emulsion
Chamber
GUN LENGTH AS SPECIFIED
BB1
BB2
BB13
B-S
BB8
BB9
A32
BB12
BB-4
BB-7
AB-2374
AB-2274
AB-2274
AB-2674
AB-2474
AB-2574
70° STD.
OR TO SUIT
1"
BB 5
AIR INLET, L.H. SIDE
1/2" I.P.S.
OIL INLET R.H. SIDE
1/2" I.P.S.
M4
BB6
BB5-S
M6
BB 3
B4

DRW'G. Nº	PART Nº		DESCRIPTION
B-100-	BB1	—	BODY
B-101-	BB2	—	CONNECTOR
B 102-	BB3	—	YOKE
B 103-	BB4	—	OIL TUBE EXTENSION
B-104-	BB5	—	INSERT
B-104-	BB5-S	—	INSERT
-	BB6	—	GASKETS- COPPER CLAD ASBESTOS 7/8" O.D. x 5/8" I.D.
B-105-	BB7	—	ADAPTER
	BB8	—	OUTER TUBE 1" DIA. SCH. 40 PIPE
———	BB9	—	INNER TUBE .540" O.D. x .088 WALL SEAMLESS MECH. STEEL TUBING
A-103-	AB-2174	—	ATOMIZER NUT
A-104-	AB-2274	—	TIP
A-105-	AB-2374	—	MIXING PLUG
B-110-	M4	—	YOKE SCREWS
B-110-	M6	—	CLAMP SCREWS
B-107-	A32	—	CENTERING BUSHING
———	BB12	—	1/4" STD PIPE COUPLING
▲ B-113-	P4	—	CLEAN OUT VALVE ASSEMBLY
▲ B-114-	B-S	—	SEAL RING WITH 1/16" ASBESTOS GASKET 2 5/8" O.D. x 1 1/2" I.D.
▲ ———	BB13	—	SEAL RING SPRING 3/32 WIRE 6 COILS 1.562" I.D. x 2 1/4 LONG
A-106-	AB-2474	—	NOZZLE
A-107	AB-2574	—	NOZZLE SEAL RING
A-108	———	—	ASS'Y. OF PARTS # AB-2474 & # AB-2574
———	AB-2674	—	VITON O RING (PARKER 2-113)

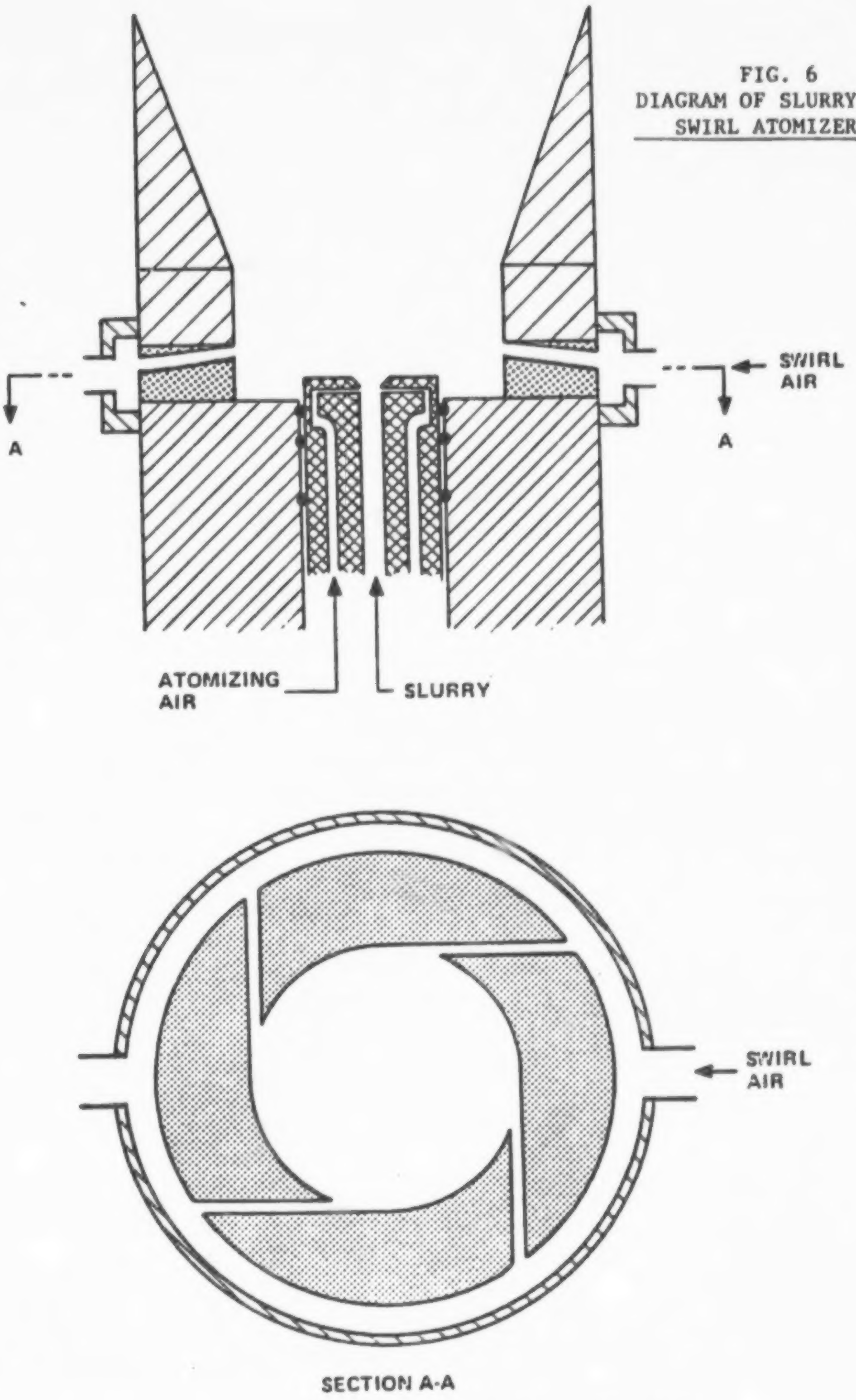
FOR Nº 2, 4, 5 & 6 FUEL OILS

GUN LENGTH AS SPECIFIED
OUTER TUBE = GUN LGT'H. -10 1/4
INNER TUBE = GUN LGT'H. -7 1/4

ITEMS MARKED ▲ FURNISHED WHEN SPECIFIED

FABER BURNER DIVISION
E. KEELER CO. WILLIAMSPORT, PENNA.
SUBJECT TYPE "AB" OIL BURNER
AB-2174 AB-2274 AB-2374 AB-2474 AB-2574
ATOMIZER ASSEMBLY
DATE 9-28-70
A-201-A

FIG. 6
DIAGRAM OF SLURRY FUEL
SWIRL ATOMIZER


SWIRL
AIR
A
A
ATOMIZING
AIR
SLURRY
SWIRL
AIR

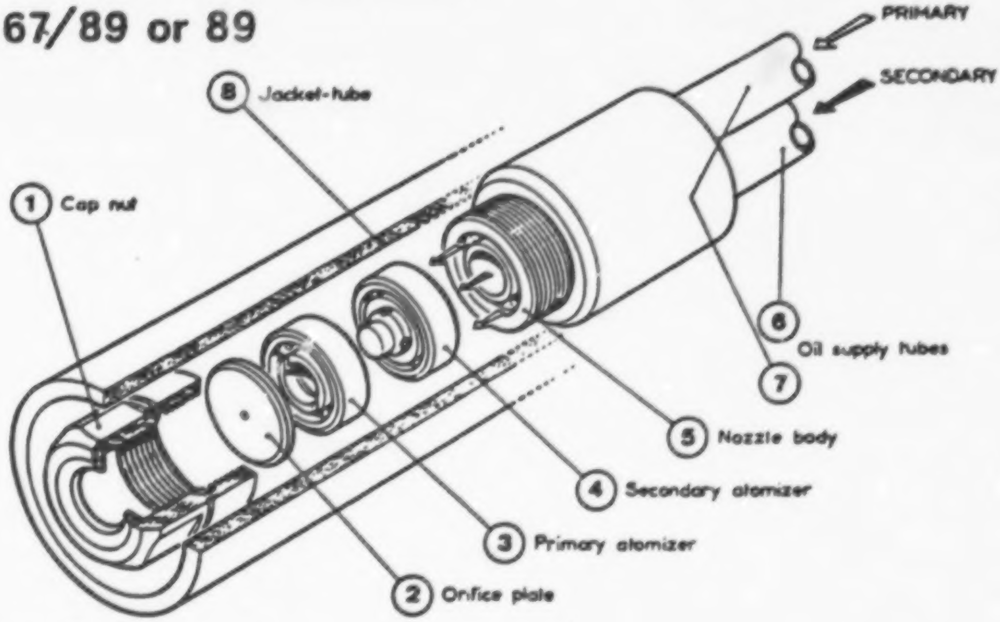
SECTION A-A

Figure 3. Diagram of Slurry Fuel Swirl Burner/Atomizer.

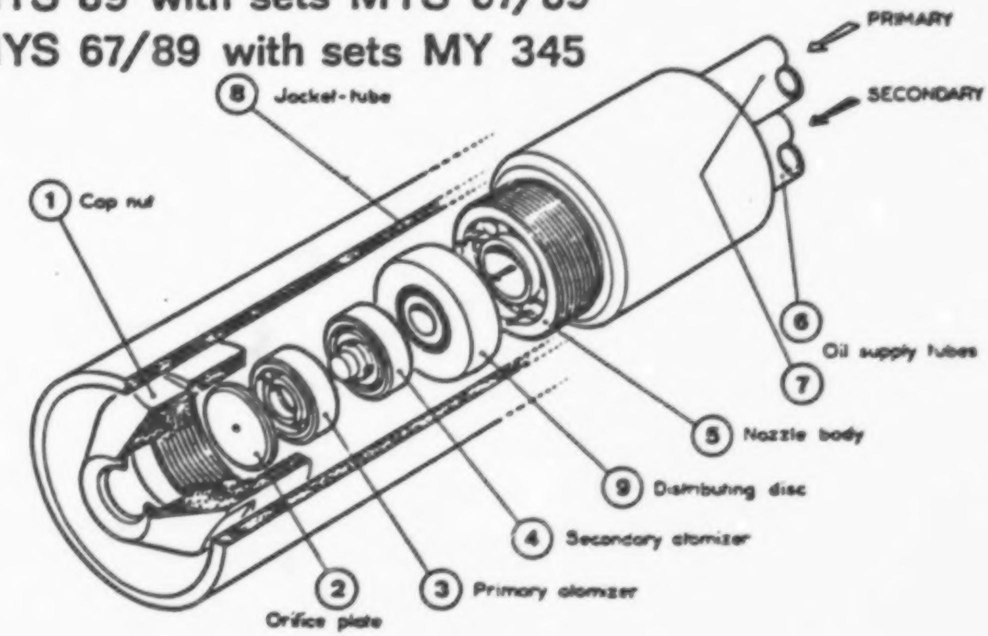
DRAWING I

FIG. 7
ATOMIZER ASSEMBLY
EXPLODED VIEW

Burner head MY-SIMPLEX 345 - 67/89 or 89


PRIMARY
SECONDARY
⑧ Jacket-tube
① Cap nut
⑥
Oil supply tubes
⑦
⑤ Nozzle body
④ Secondary atomizer
③ Primary atomizer
② Orifice plate

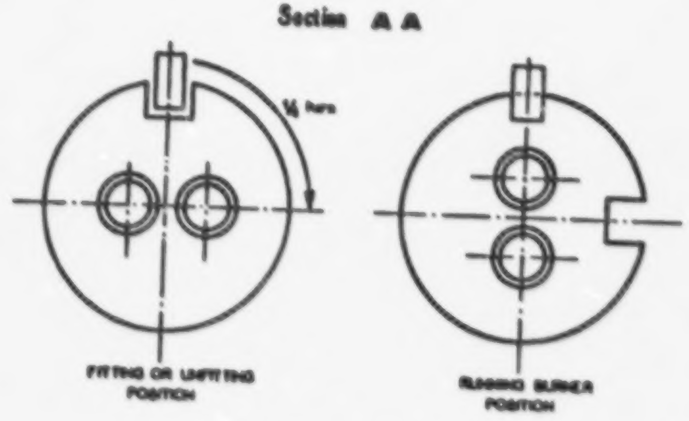
Starting fitting for MYS 89 with sets MYS 67/89 or MYS 67/89 with sets MY 345

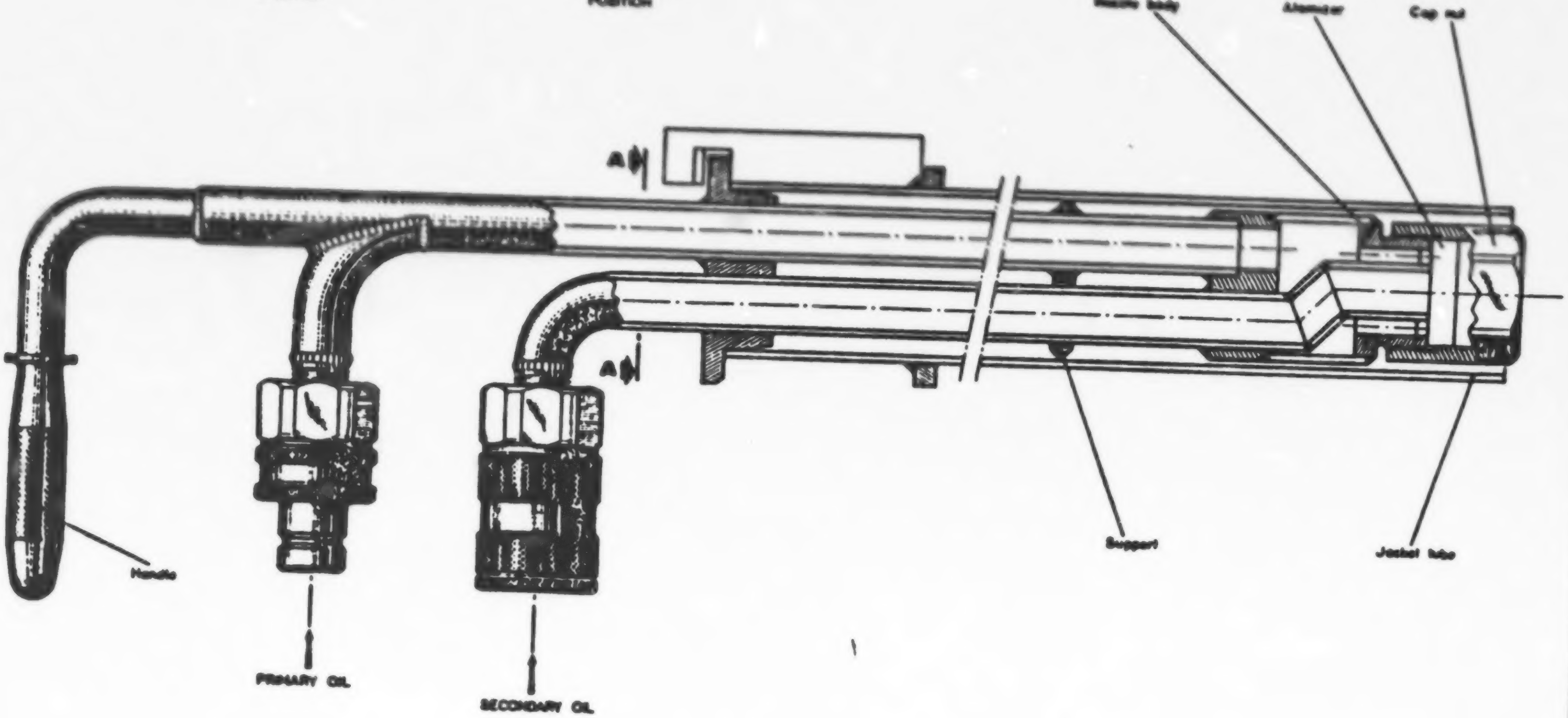

PRIMARY
SECONDARY
⑧ Jacket-tube
① Cap nut
⑥
Oil supply tubes
⑦
⑤ Nozzle body
⑨ Distributing disc
④ Secondary atomizer
③ Primary atomizer
②
Orifice plate

DRAWING II

FIG. 7.1
GENERAL ASSEMBLY
BURNER GUN

PILLARD MY Burner


Section A A
¼ turn
FITTING OR UNFITTING POSITION
RUNNING BURNER POSITION


Nozzle body
Atomizer
Cap nut
A
A
Support
Jacket tube
Handle
PRIMARY OIL
SECONDARY OIL

The Barodynamic Resonator.

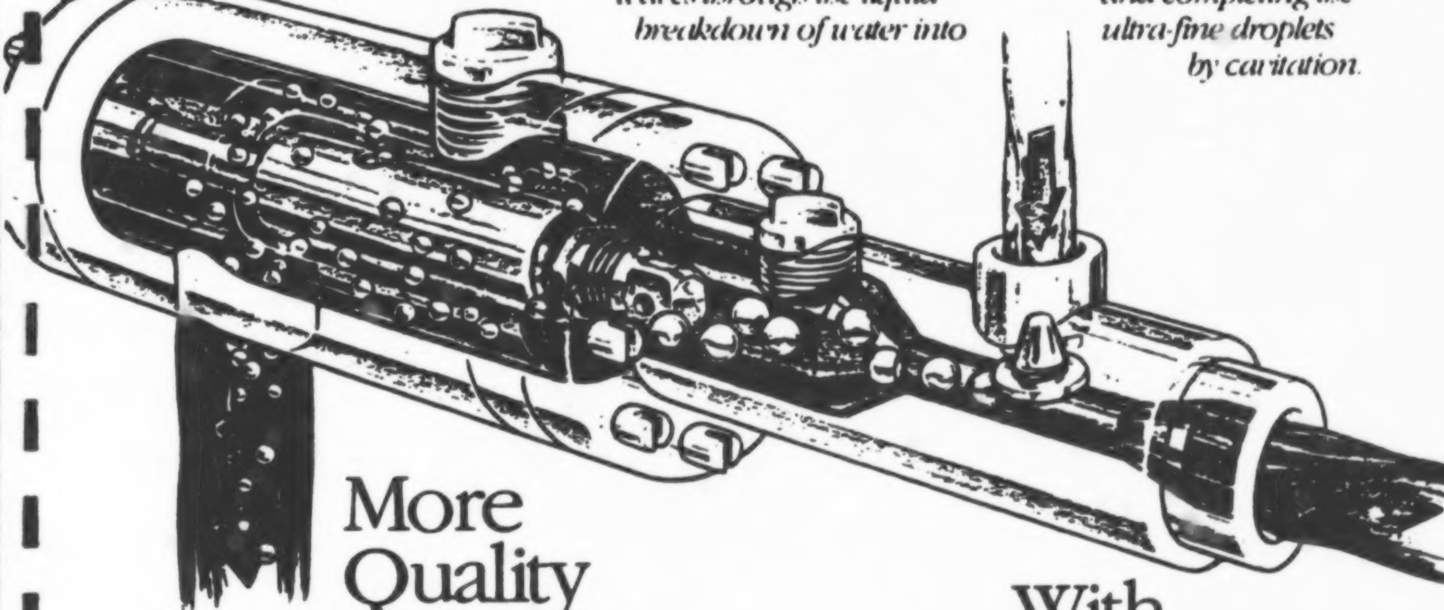
The heart of the EMULSOFIRE system is its barodynamic resonator which reduces the size of the water droplets to between 1 and 5 microns. (Independent tests have established that this size and consistency is the most desirable for a more efficient burn.) The ability to do this consistently is the key to EMULSOFIRE'S superior performance.

1. Water enters the oil stream through an atomizing nozzle.

2. Water is dispersed throughout the oil.

3. Oil and water are forced through the swirler nozzle, forming a spray.

4. Pressure from the spray causes the resonator drum to vibrate, sending shock waves through the liquid and completing the breakdown of water into ultra-fine droplets by cavitation.



More Quality Features that Set Emulsofire Apart.

- Automatic bypass prevents EMULSOFIRE from ever causing burner shutdown.
- Constant Input/Variable Output (CIVO) allows EMULSOFIRE to follow any rate of flow and maintains a constant oil-to-water ratio.
- Easy to install and simple to operate.

Emulsofire. Right for Today.

No other emulsification system offers the quality of design and manufacture that EMULSOFIRE does. Let EMULSOFIRE start saving your company money. It's been proven — the best.

With Emulsofire You May...

Burn Cheaper Oil — Lower grade fuels will burn cleanly with the efficiency of your present fuel, yet at a tremendous yearly savings.

Burn Waste Products — Spilled or waste products that formerly had no value can become an important part of your fuel supply. Emulsofire provides a double savings by simultaneously eliminating some of the expense of waste disposal and adding to your fuel efficiency.

FIG. 8
"EMULSOFIRE"
RESONATOR SECTION

FIG. 9
ICL ATOMIZER FOR COM
SKETCH PREPARED BY COURTESY
OF DATA FROM DR. KEN OLEN
OF FPLC

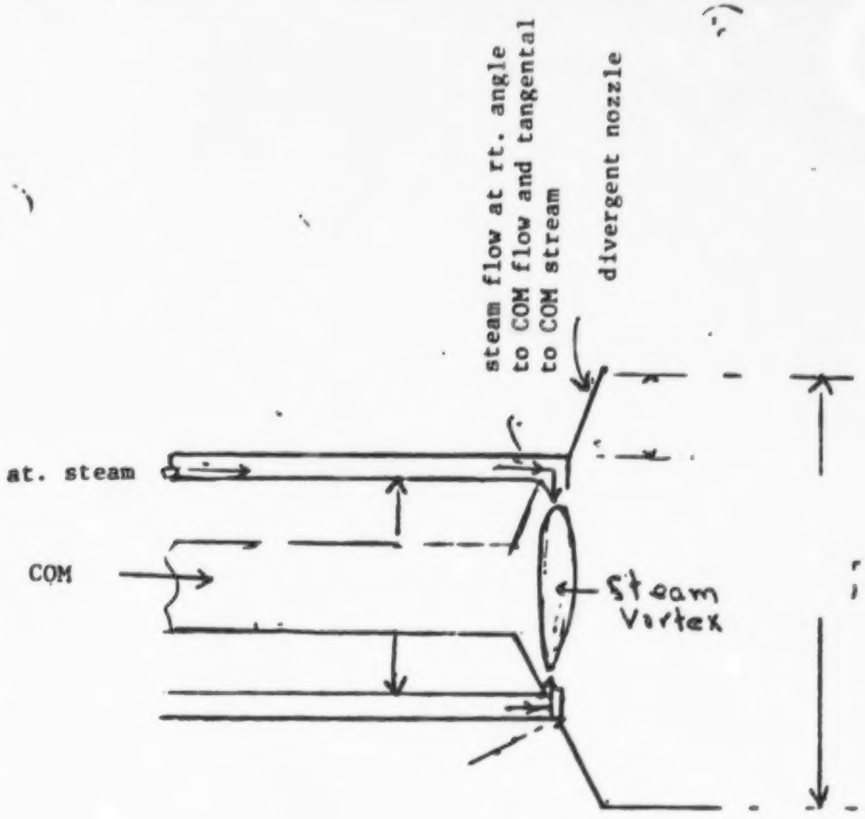

steam flow at rt. angle to COM flow and tangental to COM stream
divergent nozzle
at. steam
COM
Steam Vortex

FIG. 9

Details of a 200.10^6 BTU/HR cap. "ICL" atomizer operating on COM at the Sandford Plant of the Florida Power & Light Co.
(Courtesy of Dr. Ken R. Olen of FPLC)

16-7-82

FIG. 10
SKETCH SHOWING USE OF
NIRO COAL FLUSH DRYER
IN A UTILITY P.F.SYSTEM

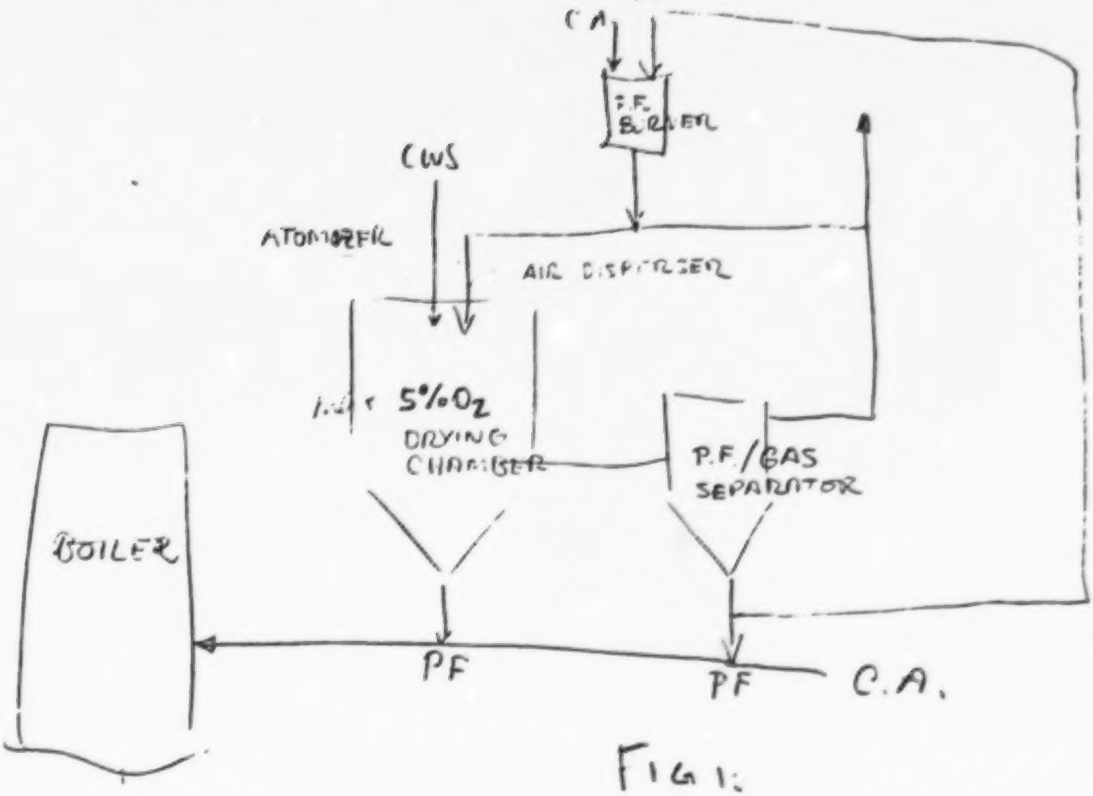

C.A
PF
P.F. BURNER
CWS
ATOMIZER
AIR DISPERSER
Max 5%O_2
DRYING CHAMBER
P.F./GAS SEPARATOR
BOILER
PF
PF
C.A.

Fig 1:

Sketch by Mr. Sten Mortenson
R+D Chief of Niro Atomizer Inc.

A Slurry Spray Drying System
with Provision of P.F. to a
Utility Boiler,

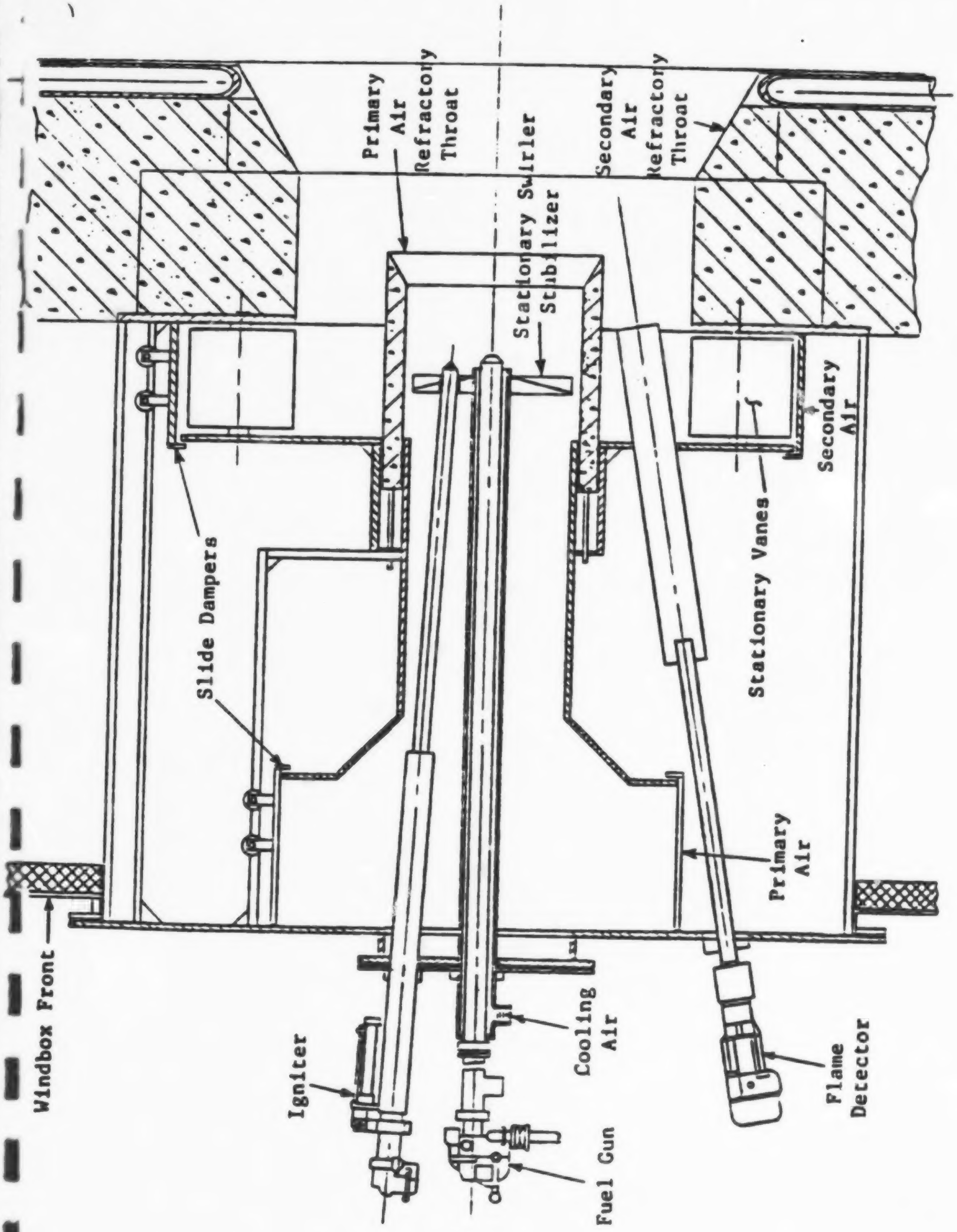

Primary Air Refractory Throat
Stationary Swirler Stabilizer
Secondary Air Refractory Throat
Secondary Air
Stationary Vanes
Slide Dampers
Primary Air
Windbox Front
Igniter
Cooling Air
Fuel Gun
Flame Detector

Figure 2.9 CWF Burner

Report Fig. 11

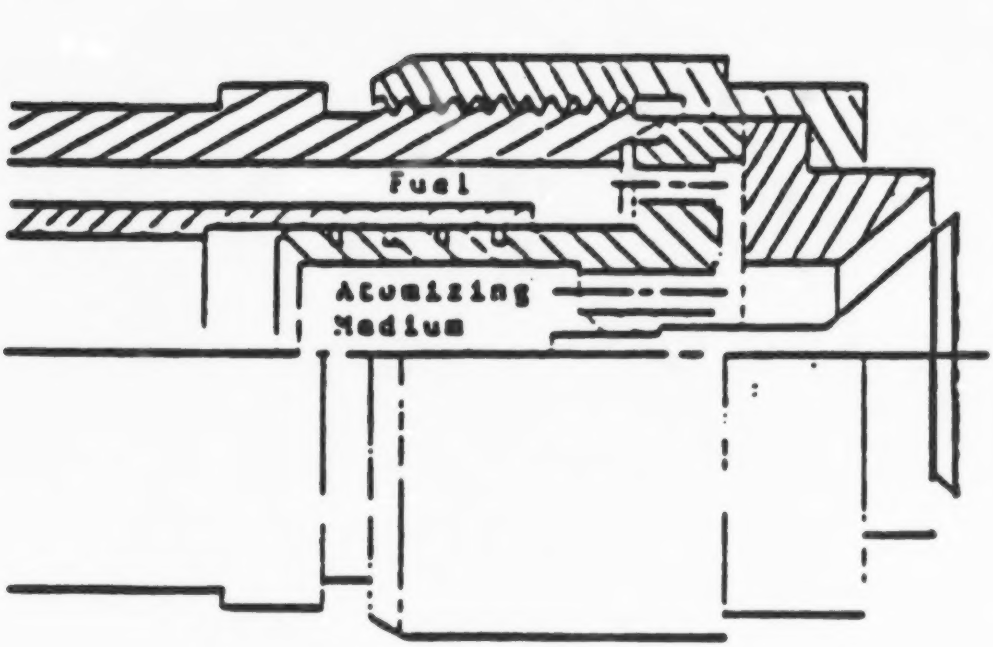

Fuel
Atomizing
Medium

FIGURE 12

Forney Conical Internal Mix Atomizer

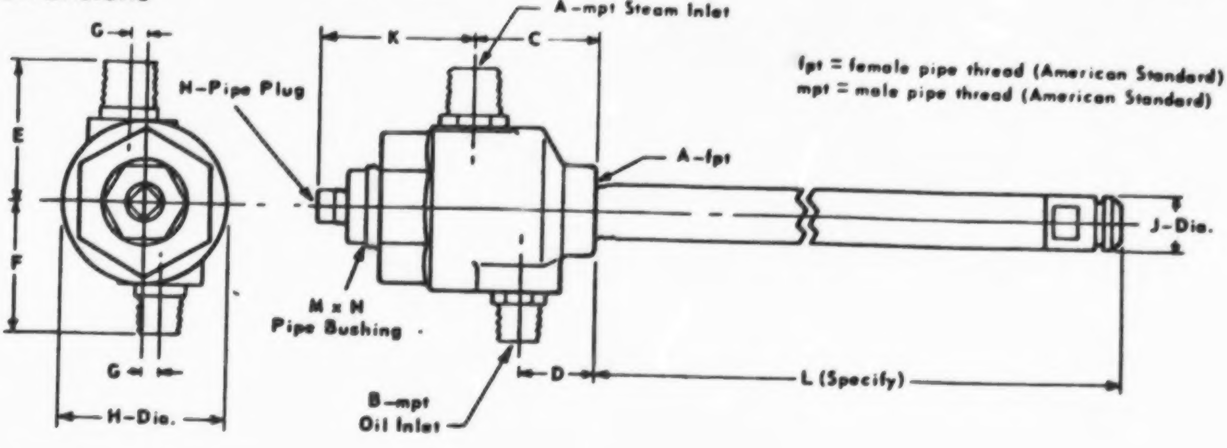
FIGURE NO. 13

NORTH AMERICAN Mfg Co
Cleveland, OH 44105 USA

GENERAL ARRANGEMENT NORTH AMERICAN BURNER GUN
NO. 5642

Bulletin 56 42, 8-82
Page 2

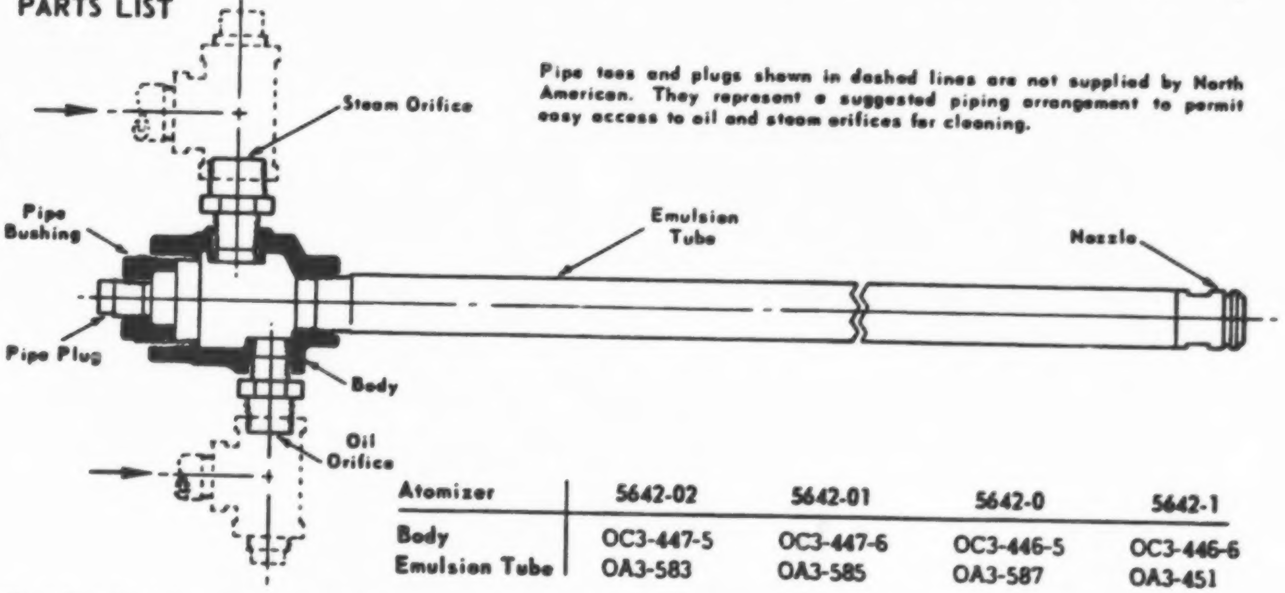
DIMENSIONS



fpt = female pipe thread (American Standard)
mpt = male pipe thread (American Standard)

Atomizer Designation	A	B	C	D	E	F	G	H	J	K	M	N
	Dimensions in inches											
5642-02	3/8	1/4	1 7/8	1 1/8	2	1 15/16	1/4	2 1/2	0.675	2 5/16	1	1/4
5642-01	1/2	3/8	1 7/8	1 1/8	2 1/8	2	1/4	2 1/2	0.840	2 5/16	1	1/4
5642-0	3/4	1/2	2 5/16	1 1/2	2 1/2	2 3/8	3/8	3	1.05	3 1/8	1 1/2	3/8
5642-1	1	3/4	2 5/16	1 1/2	2 9/16	2 1/2	3/8	3	1.315	3 1/8	1 1/2	1/2

PARTS LIST



Pipe tees and plugs shown in dashed lines are not supplied by North American. They represent a suggested piping arrangement to permit easy access to oil and steam orifices for cleaning.

Atomizer	5642-02	5642-01	5642-0	5642-1
Body	OC3-447-5	OC3-447-6	OC3-446-5	OC3-446-6
Emulsion Tube	OA3-583	OA3-585	OA3-587	OA3-451

To select the proper nozzle or orifice from this table, start with the atomizer designation in the left hand column (for example, 5642-1) and read across to the number in the table that corresponds to the last part of the atomizer model number (e.g., 140). Add the suffix from the head of the column in which the number appears (-4) to the appropriate nozzle or orifice part number (e.g. OA3-450-4).

Atomizer	Nozzle	Steam Orifice	Oil Orifice	Suffix									
				-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
5642-02	OA3-582-	OA3-1644-	OA3-1643-	5	10	15	20	25	–	–	–	–	–
5642-01	OA3-584-	OA3-1646-	OA3-1645-	30	35	40	45	50	55	60	–	–	–
5642-0	OA3-586-	OA3-1648-	OA3-1647-	65	70	75	80	85	90	95	100	–	–
5642-1	OA3-450-	OA3-1650-	OA3-1649-	110	120	130	140	150	160	170	180	190	200

To order, specify: "5642-(code for pipe size)-(capacity code) with L (specify length of "L")."
Example: 5642-02-10 3/8" Atomizer w/L dimension of 10"

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FIGURE NO. 14.1

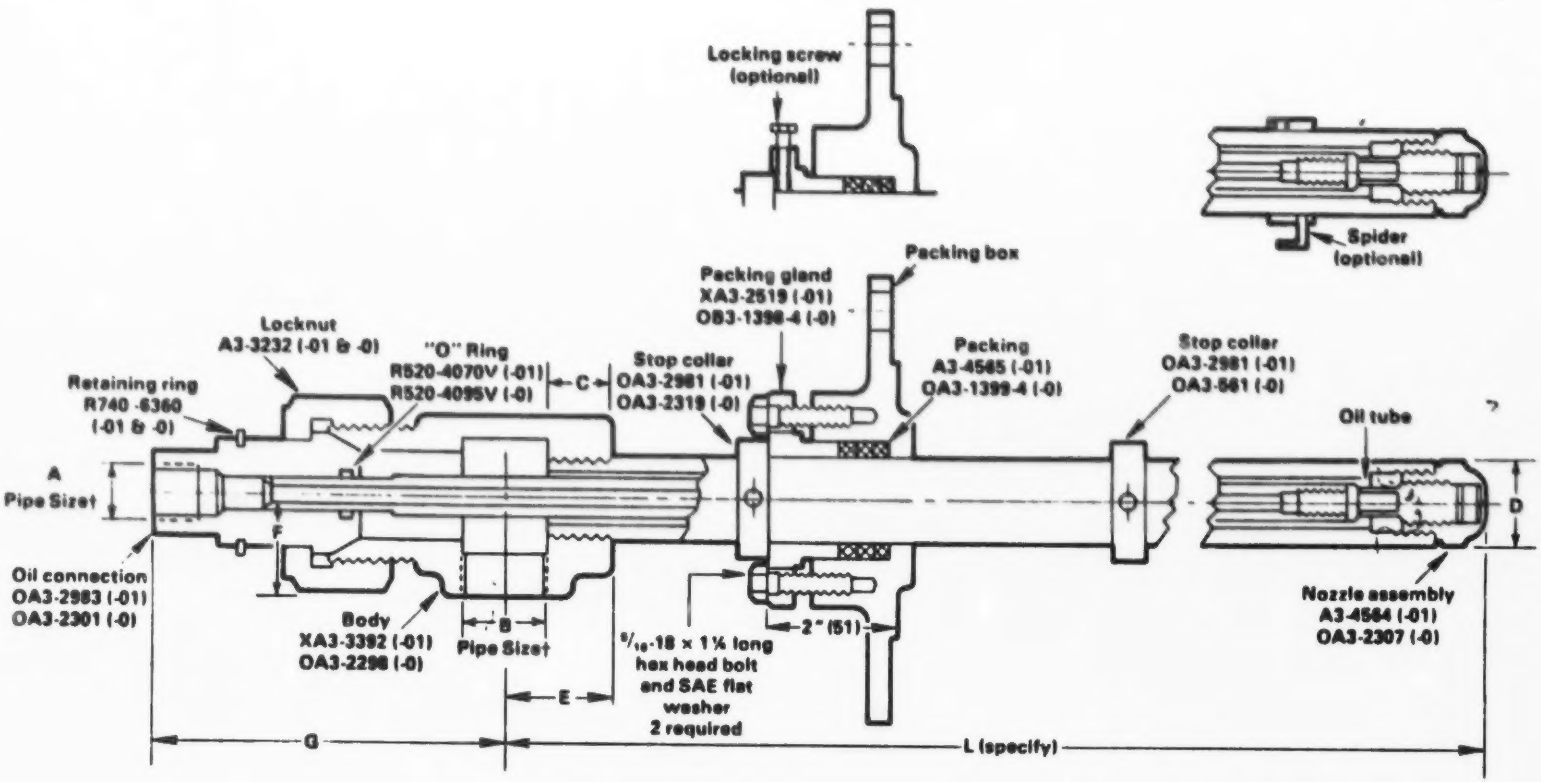
GENERAL ARRANGEMENT NORTH AMERICAN BURNER GUNS, SIZES 5643-01-0

North American-
Mfg Co
Cleveland OH 44105 USA

Series 5643 Atomizers
Parts List and Dimensions

Sheet 5643-2
6-81

Parts List and Dimensions for Series 5643 Atomizers, sizes -01 and -0.


Locking screw (optional)
Spider (optional)
Packing box
Packing gland XA3-2519 (-01) OB3-1399-4 (-0)
Packing A3-4565 (-01) OA3-1399-4 (-0)
Stop collar OA3-2981 (-01) OA3-561 (-0)
Oil tube
Locknut A3-3232 (-01 & -0)
"O" Ring R520-4070V (-01) R520-4095V (-0)
C
Stop collar OA3-2981 (-01) OA3-2319 (-0)
Retaining ring R740 -6360 (-01 & -0)
A Pipe Size†
F
Oil connection OA3-2983 (-01) OA3-2301 (-0)
Body XA3-3392 (-01) OA3-2298 (-0)
B Pipe Size†
E
5/16-18 × 1 1/4 long hex head bolt and SAE flat washer 2 required
2" (51)
D
Nozzle assembly A3-4564 (-01) OA3-2307 (-0)
G
L (specify)

Atomizer Designation	Dimensions in inches (and mm)						
	A†	B†	C	D	E	F	G
5643-01	3/8	1/2	3/4 (19)	1 (25)	1 1/4 (32)	1 3/16 (30)	4 1/8 (105)
5643-0	3/8	3/4	3/4 (19)	1 5/16 (33)	1 1/4 (32)	1 3/16 (30)	4 1/8 (105)

† = female pipe thread (American Standard)

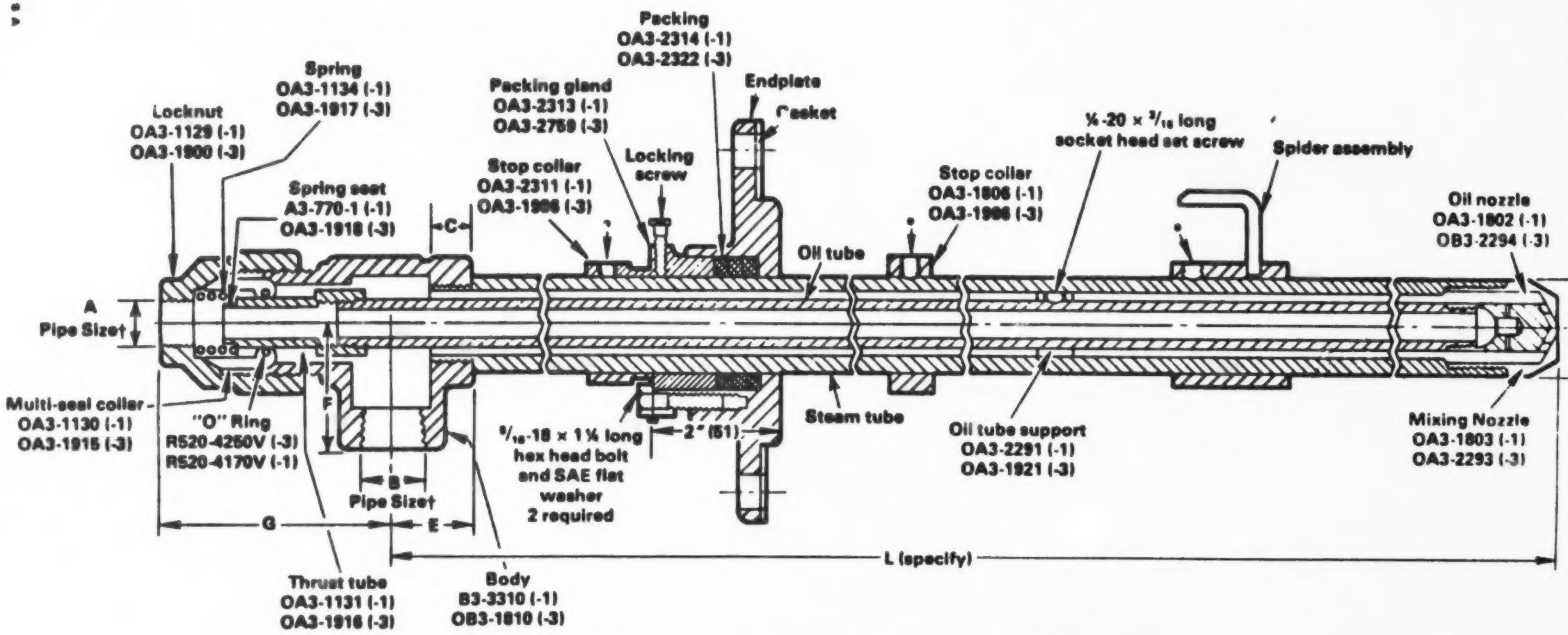
FIGURE NO. 14.2

GENERAL ARRANGEMENT NORTH AMERICAN BURNER GUNS Sizes 5643-1-3

NORTH AMERICAN Mfg. Co.
Cleveland, OH 44105 USA

Sheet 5643 2. 6-81
Page 2

Parts List and Dimensions for Series 5643 Atomizers, sizes -1 and -3.


Packing
OA3-2314 (-1)
OA3-2322 (-3)
Endplate
Gasket
Spring
OA3-1134 (-1)
OA3-1917 (-3)
Packing gland
OA3-2313 (-1)
OA3-2759 (-3)
Locknut
OA3-1129 (-1)
OA3-1900 (-3)
Locking screw
¼-20 × 3/16 long socket head set screw
Spider assembly
Stop collar
OA3-2311 (-1)
OA3-1906 (-3)
Stop collar
OA3-1806 (-1)
OA3-1906 (-3)
Spring seat
A3-770-1 (-1)
OA3-1918 (-3)
Oil nozzle
OA3-1802 (-1)
OB3-2294 (-3)
C
Oil tube
A
Pipe Size†
D
Multi-seal collar
OA3-1130 (-1)
OA3-1915 (-3)
"O" Ring
R520-4260V (-3)
R520-4170V (-1)
F
5/16-18 × 1¼ long hex head bolt and SAE flat washer 2 required
2" (51)
Steam tube
Oil tube support
OA3-2291 (-1)
OA3-1921 (-3)
Mixing Nozzle
OA3-1803 (-1)
OA3-2293 (-3)
B
Pipe Size†
G
E
L (specify)
Thrust tube
OA3-1131 (-1)
OA3-1916 (-3)
Body
B3-3310 (-1)
OB3-1810 (-3)

* ¼-20 × ¼ long socket head set screw (6 required)

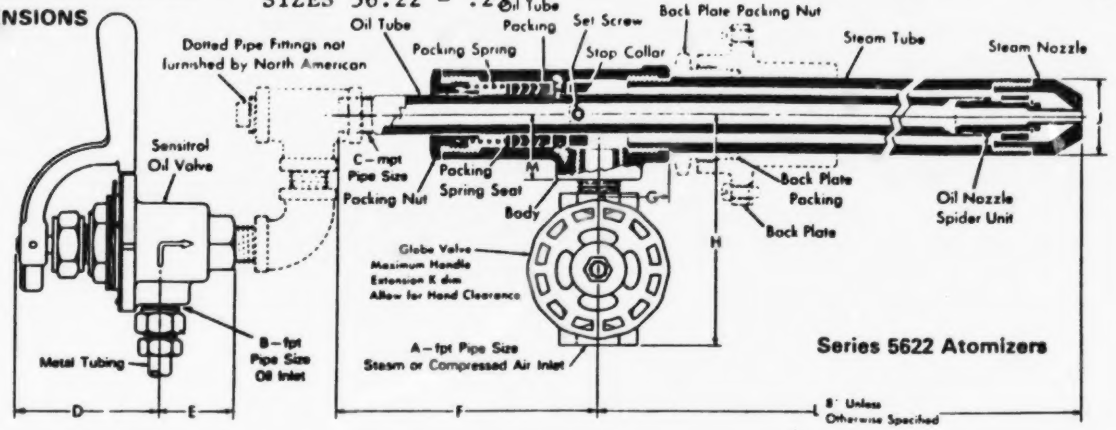
Atomizer Designation	Dimensions in inches (and mm)						
	A†	B†	C	D	E	F	G
5643-1	½	1	¾ (19)	$1\frac{11}{16}$ (43)	$1\frac{7}{16}$ (37)	$2\frac{3}{16}$ (56)	$4\frac{1}{8}$ (105)
5643-3	¾	1½	1 (25)	2½ (64)	2 (51)	$2\frac{7}{8}$ (73)	$5\frac{7}{8}$ (149)

† = female pipe thread (American Standard)

FIGURE NO. 15

GENERAL ARRANGEMENT NORTH AMERICAN BURNER GUNS SIZES 56.22 - .23

DIMENSIONS


Oil Tube
Oil Tube Packing
Set Screw
Back Plate Packing Nut
Dotted Pipe Fittings not furnished by North American
Packing Spring
Stop Collar
Steam Tube
Steam Nozzle
Sensitrol Oil Valve
C—mpt Pipe Size
Packing Nut
Packing Spring Seat
M
Body
G
Back Plate Packing
Back Plate
Oil Nozzle Spider Unit
H
Globe Valve Maximum Handle Extension K dim Allow for Hand Clearance
A—fpt Pipe Size Steam or Compressed Air Inlet
B—fpt Pipe Size Oil Inlet
Metal Tubing
D
E
F
8" Unless Otherwise Specified

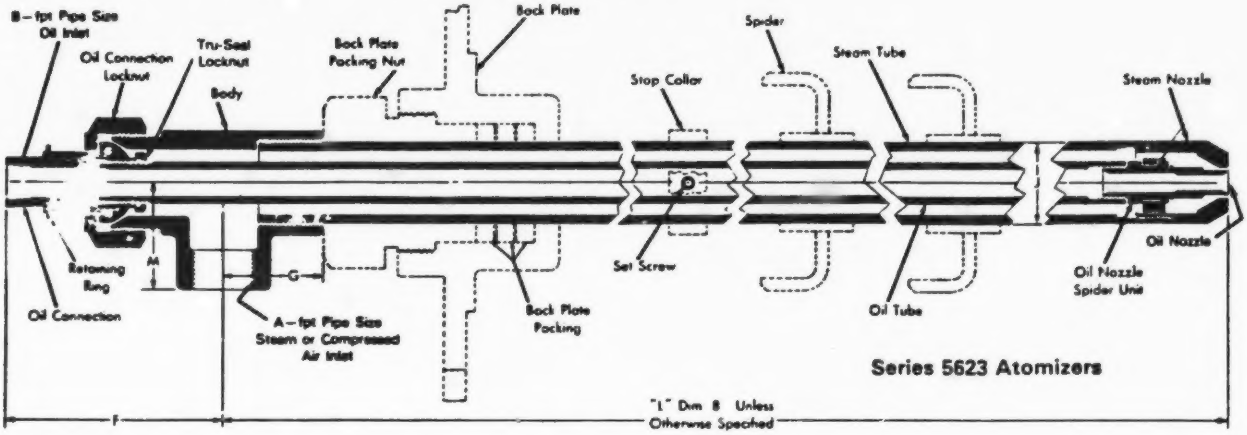
Series 5622 Atomizers

Dimensions in inches	A	B	C	D	E	F	G	H	J	K	M
5622-02-A & -02-B	3/8	3/8	3/8	2 9/16	1 5/16	5 5/8	1 1/4	3 7/8	1 3/8	4 1/2	1 3/16
5622-01-A & -01-B	1/2	3/8	3/8	2 9/16	1 5/16	5 5/8	1 1/4	4 1/8	1 3/8	5 3/16	1 3/16
5622-0-A & -0-B	3/4	1/2	1/2	3 1/16	1 5/8	6 5/8	1 7/16	5 1/8	1 5/8	5 3/4	1 9/16
5622-1-A & -1-B	1	1/2	1/2	3 1/16	1 5/8	6 5/8	1 7/16	5 1/2	1 5/8	6 5/16	1 9/16

Designation

fpt = female pipe thread (American Standard) mpt = male pipe thread (American Standard)

Metric Conversions
275 F = 135 C
1 psi = 0.0703 kg/cm²
1 gph = 0.0631 ℓ/s
1 lb = 0.4536 kg
1 scfm = 0.000 471 sm³/s
1" = 25.40 mm


B—fpt Pipe Size Oil Inlet
Oil Connection Locknut
Tru-Seal Locknut
Body
Back Plate Packing Nut
Back Plate
Spider
Stop Collar
Steam Tube
Steam Nozzle
Oil Nozzle
Set Screw
Oil Nozzle Spider Unit
Oil Tube
Retaining Ring
M
G
Oil Connection
A—fpt Pipe Size Steam or Compressed Air Inlet
Back Plate Packing
F
"L" Dim 8 Unless Otherwise Specified

Series 5623 Atomizers

PARTS LIST (Set screw is a socket head ¼-20 x 3/16", IR776-2020)

Part No.	-02-A	-02-B	-01-A	-01-B
Oil Nozzle	3-3289-1	3-3289-2	3-3289-3	3-3289-4
Steam Nozzle	3-3288-1	3-3288-2	3-3288-2	3-3288-2

Part No.	-0-A	-0-B	-1-A	-1-B
Oil Nozzle	3-3289-5	3-3289-6	3-3289-7	3-3289-8
Steam Nozzle	3-3287-1	3-3287-2	3-3287-2	3-3287-2

Dimensions in inches	A	B	F	G	J	M
5623-02-A & -02-B	3/8	3/8	4 3/16	1 1/4	1 3/8	1 3/16
5623-01-A & -01-B	1/2	3/8	4 3/16	1 1/4	1 3/8	1 3/16
5623-0-A & -0-B	3/4	1/2	4 3/8	1 7/16	1 5/8	2 3/16
5623-1-A & -1-B	1	1/2	4 3/8	1 7/16	1 5/8	2 3/16

Designation

To order, specify: "5622(or 5623)-(code for pipe size)-(letter for capacity) Atomizer Only with L (specify "L" dimension)."
Example: 5623-02-A 3/8" Atomizer w/L dimension of 10"

Part No.	5622-02-A&-B	5622-01-A&-B	5622-0-A&-B	5622-1-A&-B
Body	3-760-3	3-760-2	3-724-3	3-724-2
Copper Tubing	3-310-7	3-310-7	3-310-8	3-310-8
Globe Valve	1832-02	1832-01	1832-0	1832-1
Oil Tube	3-766-2	3-766-2	3-773-2	3-773-2
O. T. Packing	3-1069-1	3-1069-1	3-1069-2	3-1069-2
Packing Nut	3-767-2	3-767-2	3-774-2	3-774-2
Packing Spring	3-769-1	3-769-1	3-769-1	3-769-1
Packing Seat	3-770-1	3-770-1	3-770-2	3-770-2
Sensitrol	1813-02-C	1813-02-D	1813-01	1813-01
Steam Tube	3-3298-1	3-3298-1	3-772-1	3-772-1
Stop Collar	3-761-3	3-761-3	3-761-4	3-761-4

Part No.	5623-02-A&-B	5623-01-A&-B	5623-0-A&-B	5623-1-A&-B
Body	3-3307-2	3-3307-1	3-3310-2	3-3310-1
Oil Connection	3-3233-1	3-3233-1	3-3308-1	3-3308-1
Oil Connection Locknut	3-3232-1	3-3232-1	3-3309-1	3-3309-1
Oil Tube	3-3306-1	3-3306-1	3-3301-1	3-3301-1
Retaining Ring	IR740-6360	IR740-6360	IR740-6390	IR740-6390
Tru-seal Locknut	IR790-0115		IR790-0120	

Dotted parts other than pipe fittings are for mounting atomizer inside a burner. To replace these, specify part name, atomizer series, burner series and size.

Parts not listed for Series 5623 Atomizers are the same as for Series 5622 Atomizers.

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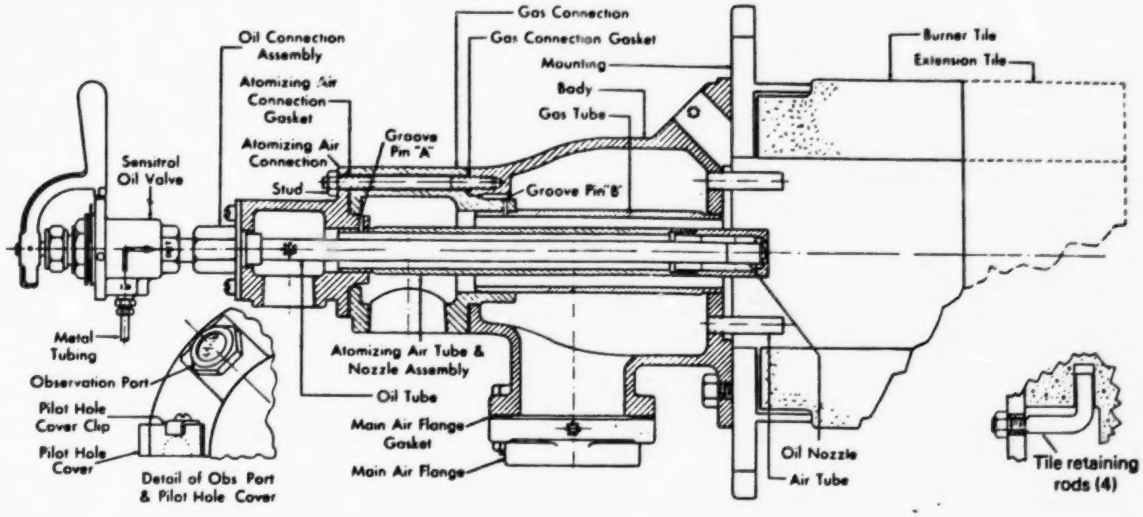
FIGURE NO. 16

GENERAL ARRANGEMENT NORTH AMERICAN BURNER MODEL 64.22 - LAP

North American
Mfg. Co.
Cleveland, OH 44105 USA

6422 Dual-Fuel and 5422 Oil Burners

PARTS LIST 64.22
4-81


Gas Connection
Gas Connection Gasket
Mounting
Body
Gas Tube
Burner Tile
Extension Tile
Oil Connection Assembly
Atomizing Air Connection Gasket
Atomizing Air Connection
Groove Pin "A"
Stud
Groove Pin "B"
Sensitrol Oil Valve
Metal Tubing
Observation Port
Pilot Hole Cover Clip
Pilot Hole Cover
Detail of Obs Port & Pilot Hole Cover
Atomizing Air Tube & Nozzle Assembly
Oil Tube
Main Air Flange Gasket
Main Air Flange
Oil Nozzle
Air Tube
Tile retaining rods (4)

Part Name / Part Number	5422-2 6422-2	5422-3 6422-3	5422-4 6422-4	5422-5 6422-5	5422-6 6422-6	5422-7-A 6422-7-A	5422-7-B 6422-7-B	5422-8-A 6422-8-A
Air Tubes (8 req'd)	3-2472-12	3-2472-5	3-3640-1	3-3639-1	3-3554-1	3-3273-3	3-3273-4	4-3684-2
Atom. Air Tube & Nozzle Assembly①	←	3-2887-3	→	3-2887-2	3-2887-2	3-2887-4	3-2887-4	3-6076-2
Atomizing Air Connection	←	3-2474-1	→	3-2474-2	3-2474-2	3-3324-1	3-3324-1	3-6081-1
Atomizing Air Conn. Gasket	←	←	3-3343-1	→	→	3-3326-2	3-3326-2	3-3326-2
Body	←	3-2466-9	→	→	3-2466-10	3-3267-3	3-3267-3	3-3267-4
Burner Tile (9")	←	←	4-2121-2	→	→	4-2142-2	4-2142-2	4-2142-2
Burner Tile (5½")	←	←	4-2121-1	→	→	–	–	–
Extension Tile	←	←	4-1737-3	→	→	–	–	–
Gas Connection②	3-2465-4	3-2465-4	3-2465-5	3-2465-6	3-2465-6	3-3268-2	3-3268-2	3-6073-1
Gas Connection Gasket②	←	←	3-2473-1	→	→	3-3272-1	3-3272-1	3-3272-1
Gas Tube②	←	←	3-2468-2	→	→	③	③	③
Groove Pin "A"	←	←	IR570-2277	→	→	IR570-2310	IR570-2310	IR570-2310
Groove Pin "B"②	←	←	IR570-2300	→	→	–	–	–
Main Air Flange	3-2544-2	3-2544-1	4-1695-2	4-1695-3	4-1695-9	4-1695-5	4-1695-5	2-1210-2
Main Air Flange Gasket	←	←	4-5371-2	→	→	4-2678-2	4-2678-2	4-2678-2
Metal Tubing	←	←	←	3-0310-7	→	→	→	→
Mounting (Cast)	←	←	3-3257-1	→	→	3-3270-1	3-3270-1	3-3270-1
Observation Port	←	←	←	8790-0	→	→	→	→
Oil Connection Assembly	←	←	←	3-2391-1	→	→	→	3-2519-2
Oil Tube①	←	3-2470-1	→	→	3-2470-2	3-2470-8	3-2470-8	3-2515-1
Oil Nozzle	←	3-2541-1	→	→	3-1056-4	3-2541-1	3-2541-1	3-6077-1
Pilot Hole Cover	←	←	←	4-2628-2	→	→	→	→
Pilot Hole Cover Clip	←	←	4-2629-1	→	→	–	–	–
Tile Retaining Rod (4 req'd) (Cast Mtg.)	←	←	3-1115-1	→	→	3-2531-1	3-2531-1	3-2531-1
Sensitrol Oil Valve	←	1813-02-A	→	→	1813-02-B	1813-02-C	1813-02-C	1813-02-C
Stud (4 req'd)①	←	←	3-2584-1	→	→	3-3325-1	3-3325-1	3-3325-1

①Used on 6422 only. See below for corresponding 5422 part.
②Not used on 5422.
③Gas tube and gas connection are integral on 6422-7-A, -7-B, and -8-A.

PARTS for 5422 Oil Burners Only

Part Number	5422-2	5422-3	5422-4	5422-5	5422-6	5422-7-A	5422-7-B	5422-8-A
Atom. Air Tube & Nozzle Assembly	←	3-3484-1	→	3-3484-2	3-3484-2	3-3484-3	3-3484-3	3-6376-1
Oil Tube	←	3-2470-5	→	→	3-2470-6	3-2470-9	3-2470-9	3-6377-1
Screw (replaces Stud) 4 req'd	←	←	IR066-2640-H	→	→	IR066-2930-H	IR066-2930-H	IR066-2930-H

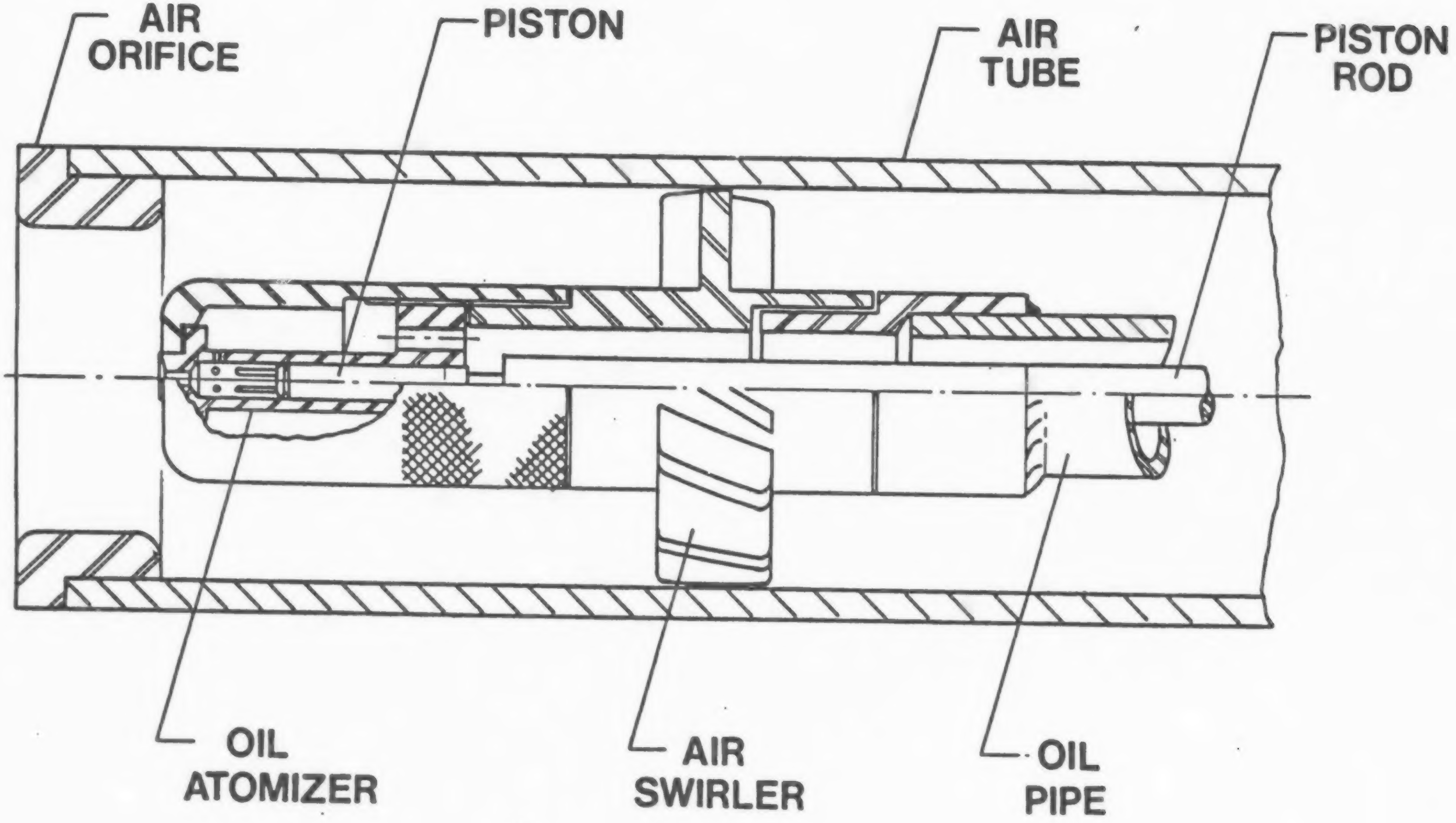
ORDER MUST SPECIFY: 1. Part Number 2. Part Name 3. Burner Designation

Figu[illegible].1

General Arrangement AECO Atomizer and Gun for Kiln Application, With Air Assist Atomization

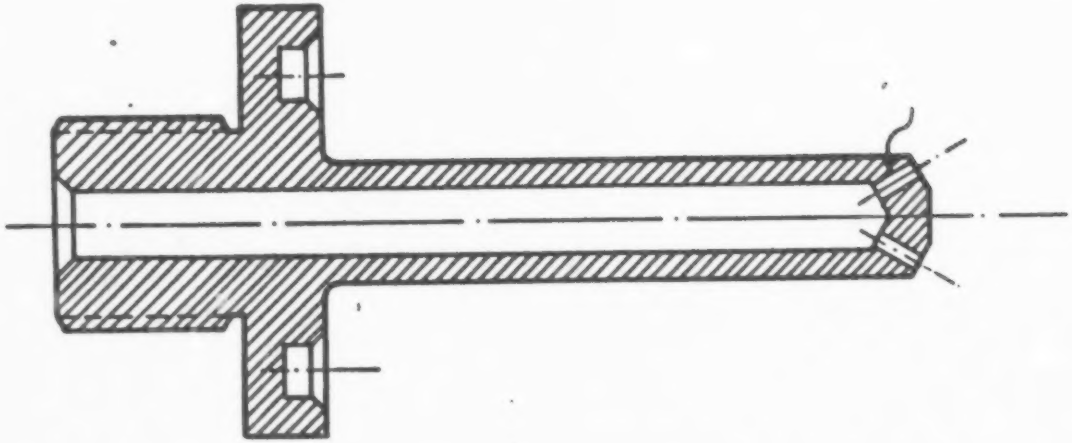
FUEL OIL KILN BURNER

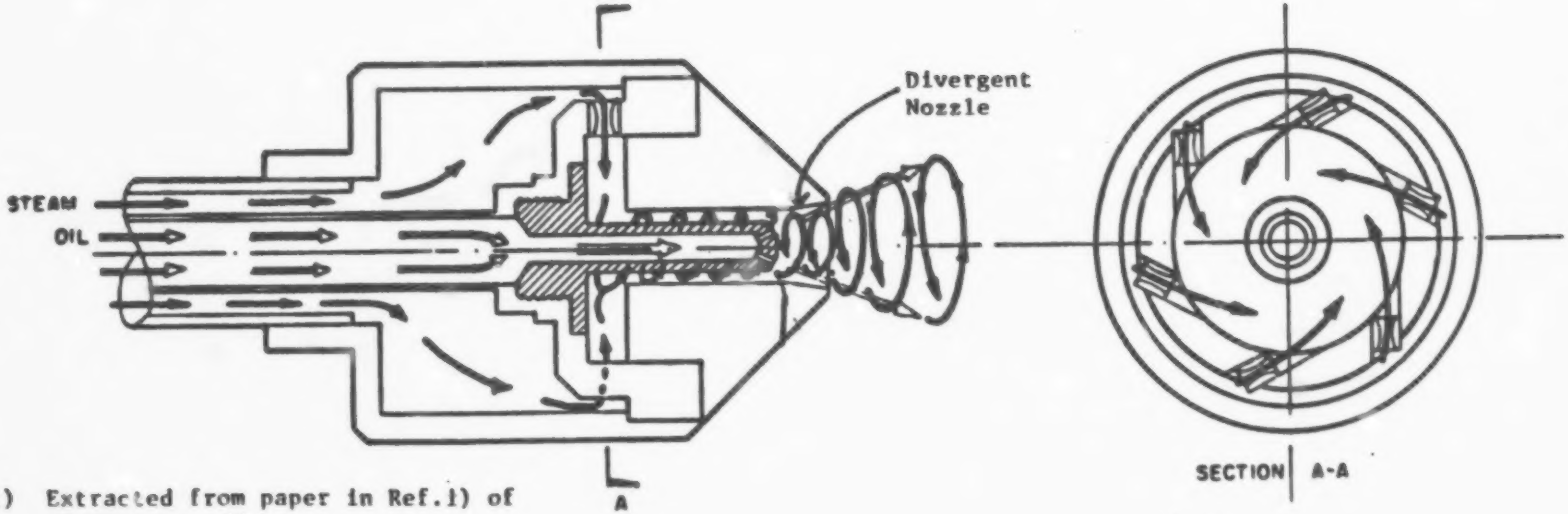
(WITH AIR ASSIST ATOMIZATION)


AIR ORIFICE
PISTON
AIR TUBE
PISTON ROD
OIL ATOMIZER
AIR SWIRLER
OIL PIPE

[1] Fig. No. 18

Vortometric Burner Fuel Tip




A
A
STEAM
OIL
Divergent Nozzle
SECTION A-A

VORTOMETRIC BURNER FUEL TIP (EXTERNAL ATOMIZATION)

---

[1] Extracted from paper in Ref.1) of Report No. 25

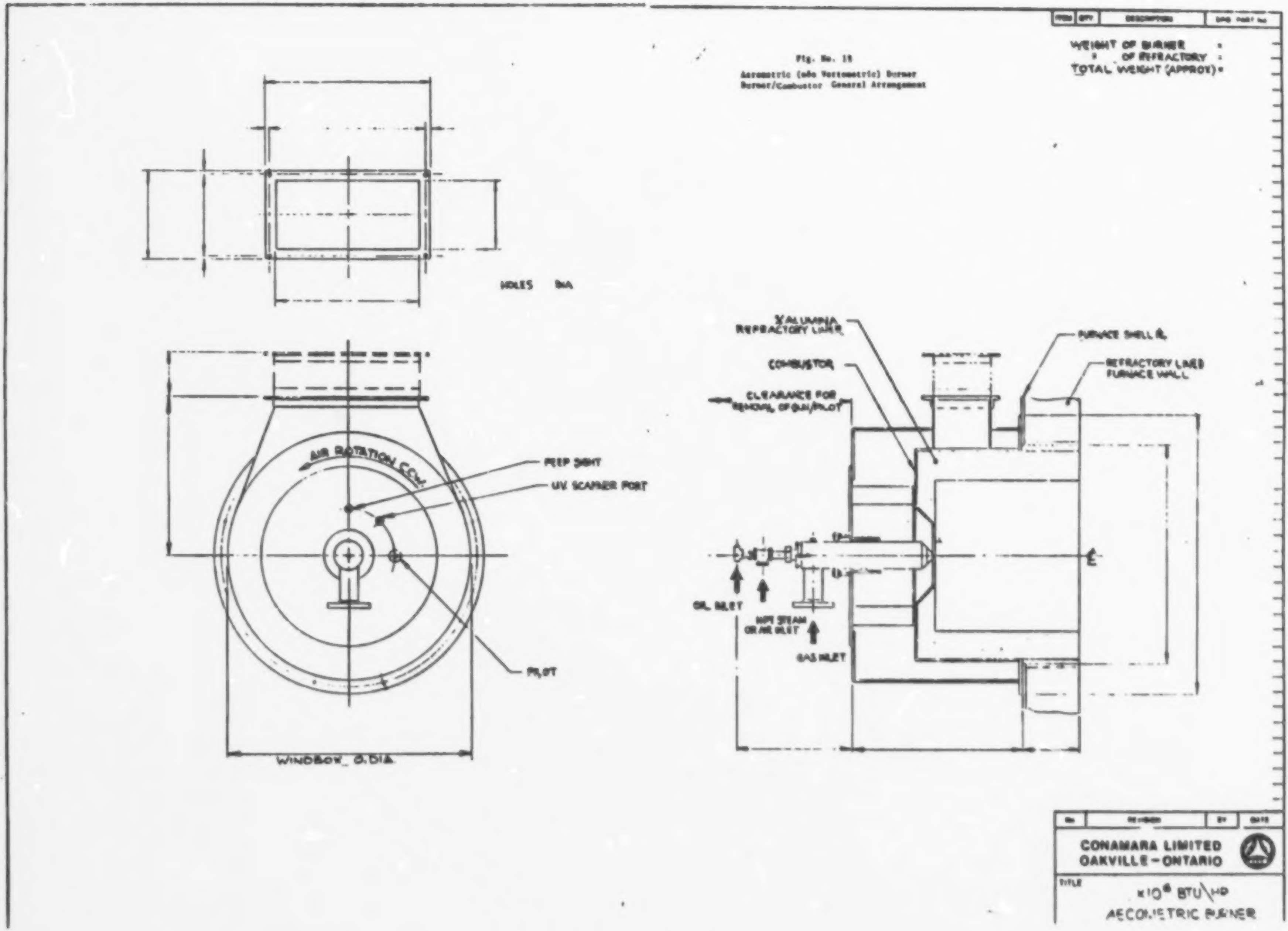

ITEM
QTY
DESCRIPTION
DWG PART No.
WEIGHT OF BURNER :
" OF REFRACTORY :
TOTAL WEIGHT (APPROX) =
HOLES DIA
AIR ROTATION C.C.W.
PEEP SIGHT
U.V. SCANNER PORT
PILOT
WINDBOX O.DIA.
X ALUMINA REFRACTORY LINER
COMBUSTOR
CLEARANCE FOR REMOVAL OF GUN/PILOT
FURNACE SHELL ℄
REFRACTORY LINED FURNACE WALL
℄
OIL INLET
HOT STEAM OR AIR INLET
GAS INLET
No.
REVISION
BY
DATE
CONAMARA LIMITED
OAKVILLE-ONTARIO
TITLE
$\times 10^{6}$ BTU\HR
AEROMETRIC BURNER

Fig. No. 10

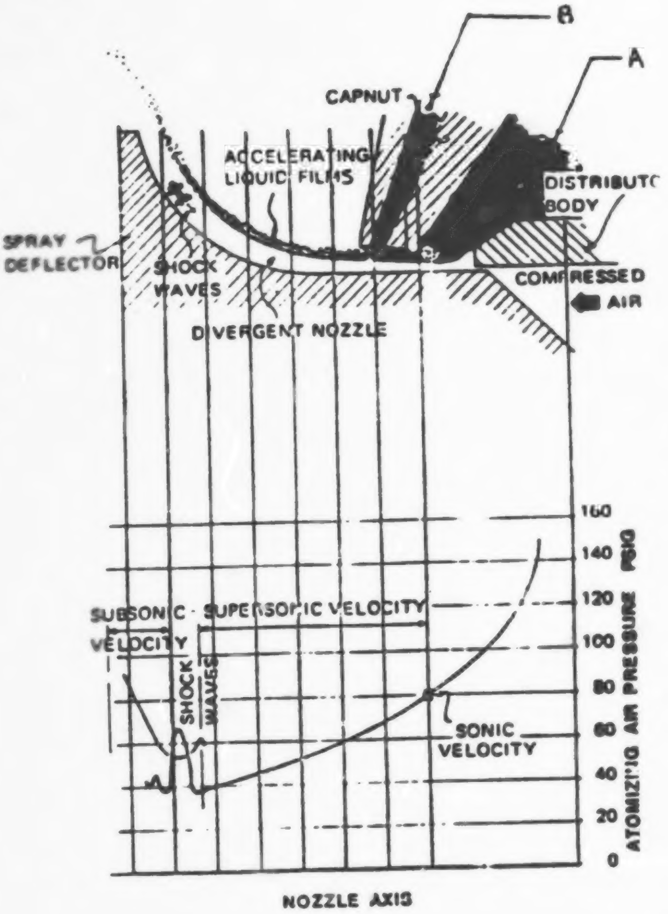
Aerometric (née Vortometric) Burner
Burner/Combustor General Arrangement

FIGURE [illegible]
SCHEMATIC OF FLUID KINETICS LTD.
FLO-SONICS ATOMIZER FOR ATOMIZATION
OF TWO OR MORE FLUIDS

FloSonic® **SUPERSONIC ATOMIZATION**

ML SERIES

FOR MIXING & ATOMIZATION OF TWO OR MORE LIQUID PHASES


B
A
CAPNUT
ACCELERATING LIQUID FILMS
DISTRIBUTOR BODY
SPRAY DEFLECTOR
SHOCK WAVES
COMPRESSED AIR
DIVERGENT NOZZLE
SUBSONIC VELOCITY
SUPERSONIC VELOCITY
SHOCK WAVES
SONIC VELOCITY
160
140
120
100
80
60
40
20
0
ATOMIZING AIR PRESSURE PSIG
NOZZLE AXIS

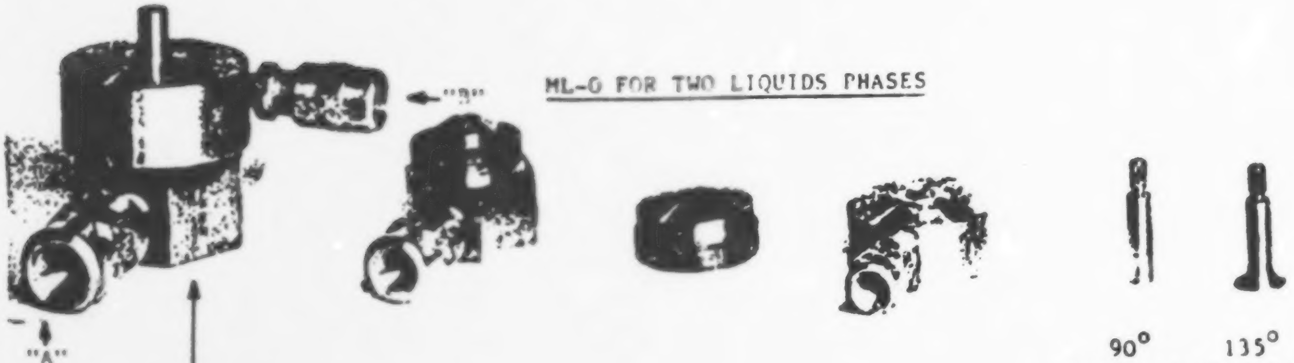
PRINCIPLE OF OPERATION:

Part A & B are separately metered into the nozzle. The layers of liquid pass from the nozzle into a sonic field where shock waves simultaneously mix and atomize the liquids. Capacities available through 48 [illegible].

TYPICAL APPLICATIONS:

- Emulsifying oils with water.
- 2-part urethane foam mixing and spraying.
- Combining two or more chemicals, food products, etc.
- Fuel/wastewater disposal by spray burning.

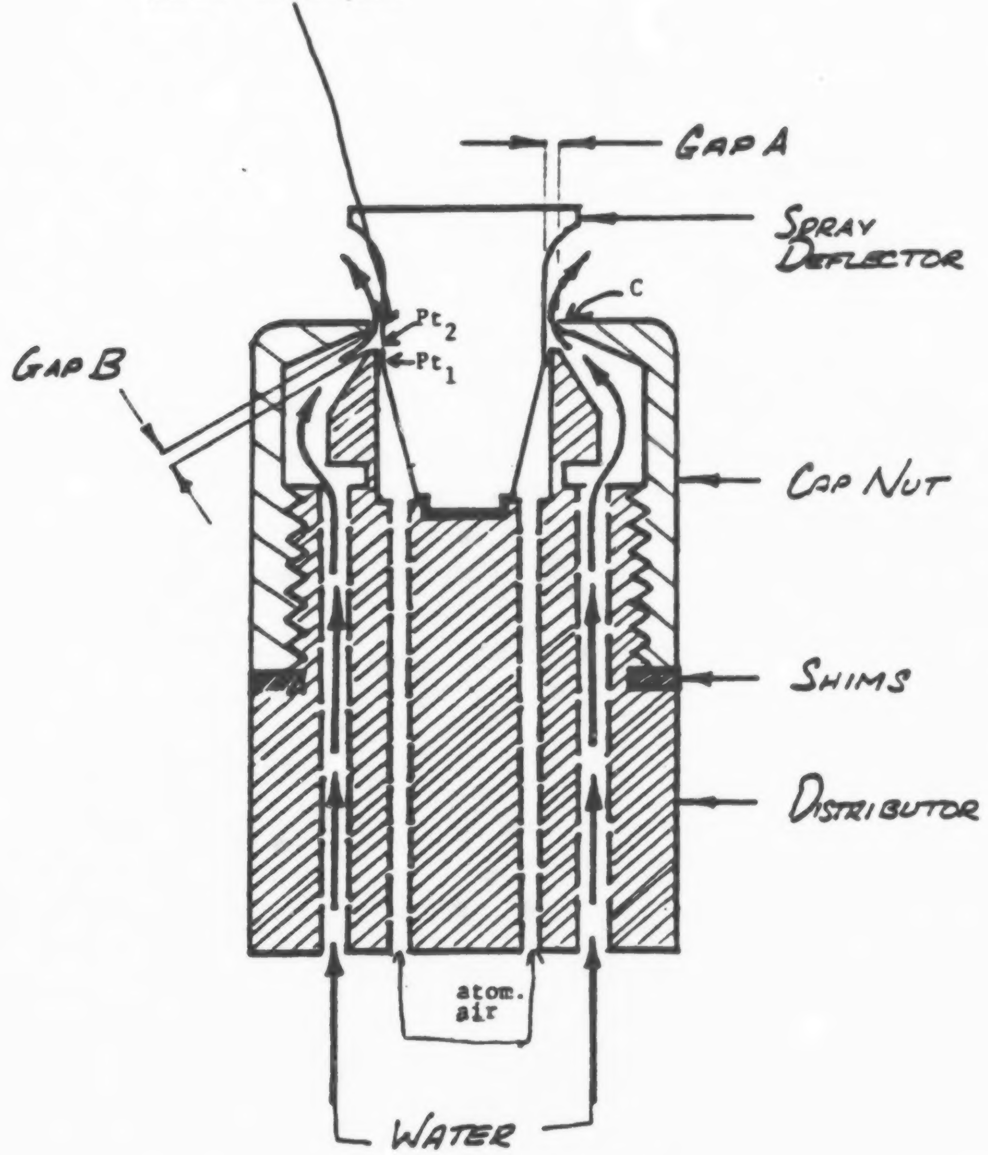
ML-G FOR TWO LIQUIDS PHASES



AIR, STEAM, ETC.

SPRAY DELFECTORS

U. S. Patent [illegible] & other patents pend



This gap area designed to flow (for erosion test) 25 scfm with Pt_1 of 114.7 psia and Pt of (.53 x 114.7) = 60.8 psia for ΔP of 54 psi.

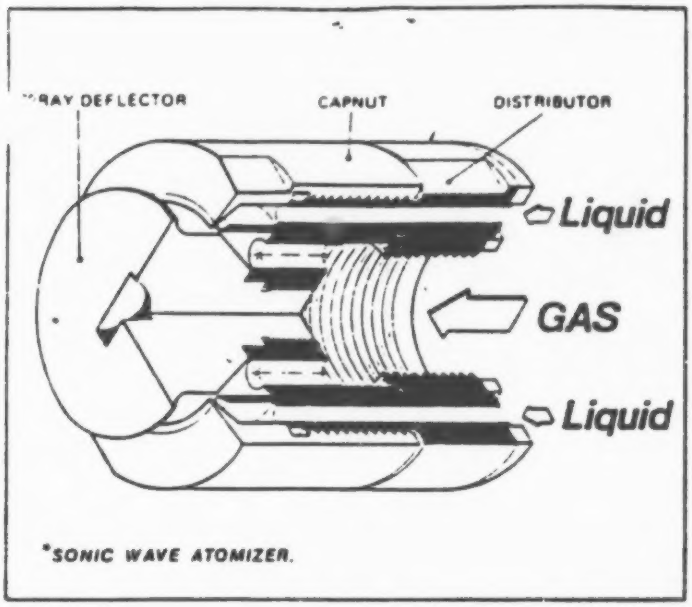
GAP A
SPRAY DEFLECTOR
C
Pt_2
Pt_1
GAP B
CAP NUT
SHIMS
DISTRIBUTOR
atom. air
WATER

FIG. 21 SCHEMATIC OF FLO-SONICS ATOMIZER FUNCTION

NOTES: a) Shims determine Gap B

b) Gap A determined by 1) diameter of spray deflector and I.D of Cap Nut at Pt. C.

FIG. 22 SCHEMATIC OF FLO-SONICS ATOMIZER FOR SINGLE CLM FUEL



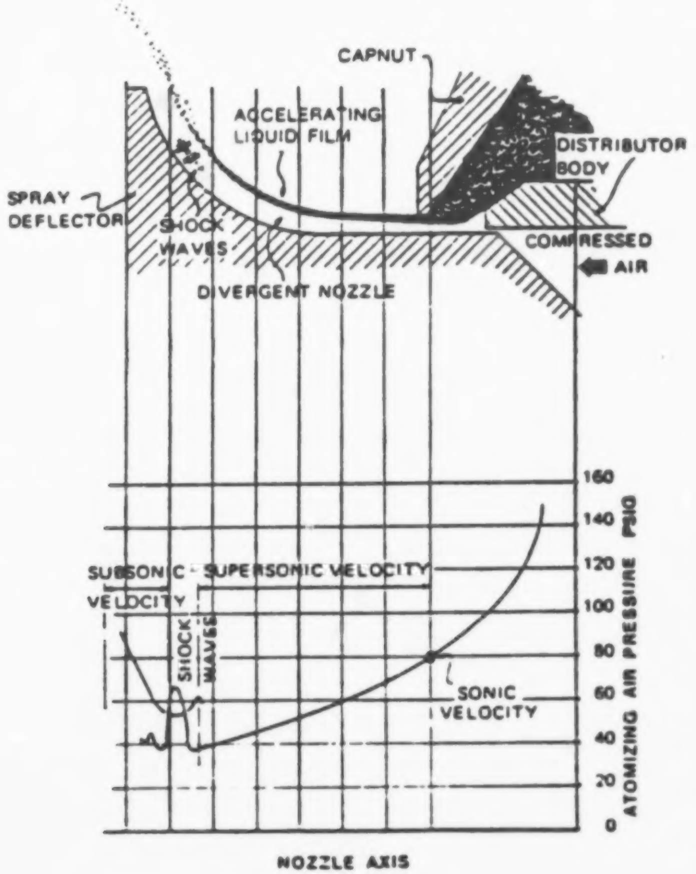
APPLICATIONS INCLUDE

Hot Gas Cooling and Conditioning for Cement and Steel Plants
Municipal Incineration.
Humidification and Conditioning of air.
Spray Cooling.
Oil Fogging.
Gas Scrubbing.
Dust Suppression.
Insecticide Fogging.
Ultra Low Volume Spraying.
Edible Fat Spraying.
Blending Processes.
Perfume Spraying.
Acid Spraying.
Fuel Oil Combustion
Carbon Black Processing.
Agricultural Sprayers.
Dry and Wettable Powder Dispersion.
Paint Spraying.

POLLUTION CONTROL

*FloSonic** atomizers are used to control air and water pollution from many sources. They solve numerous problems in combustion, incineration, wet scrubbing, fume control and waste treatment.

*FloSonic** Engineering Department will consider and advise on any application for special cases not specified within this brochure. Please supply the information listed on back page.



THE SONIC WAVE TWIN FLUID ATOMIZER

The atomizers are available in standard sizes to handle a flow range of 6 to 2,400 GPH. Ultra low or higher flow atomizers are available on special order.

For all practical purposes, these atomizers have an infinite turn-down ratio; unlike many other mechanical and twin fluid atomizers, the liquid droplet size reduces rapidly with the decrease in liquid flow.

OPERATING PRINCIPLE

An exploded view of the atomizer is shown above. It consists of three components: Spray deflector, Capnut and Distributor.

Compressed air is delivered to a chamber formed by the spray deflector and distributor. The outlet from this chamber is an accurately sized concentric annular nozzle. The air flows from this nozzle at sonic velocity underneath the exit from the outer annular liquid chamber formed by the capnut and distributor.

The liquid film is accelerated by the air and is reduced and sheared.

The compressed air expands during this stage and forces the liquid away from the surface of the spray deflector forming an effective divergent nozzle between the spray deflector and liquid film. Supersonic velocities are attained culminating in violent pressure fluctuations. The shock waves vibrate the liquid layer causing further shearing and break-up occurs in a plane perpendicular to the horizontal shearing. Atomization is complete and the spray diverges at an angle determined by the final diameter of the spray deflector.

The air cushion between the spray and the spray deflector prevents re-entrainment of droplets and wetted metallic surfaces which invariably give rise to a small but troublesome percentage of large droplets.

The plot of air pressure vs nozzle axis is a simplified representation of the actual expansion process.

COMPRESSED AIR REQUIREMENTS

Compressed air from reciprocating machinery is expensive per unit volume but is relatively inexpensive for low volumes and high pressures. For this reason the Sonic Wave Atomizer was designed to operate with an air mass-pressure ratio of 0.03 and it is possible to atomize 960 GPH of water using only 40 SCFM of air at a pressure of 100 PSIG, a power-water ratio slightly better than 0.01 HP/GPH.

FIG. 23 PATENT DRAWING & PATENT NUMBERS FOR FLO-SONICS ATOMIZER

3

United States Patent [19]

Koppehele et al.

[11] **4,361,285**

[45] **Nov. 30, 1982**

[54] **MIXING NOZZLE**

[75] Inventors: **Hugh P. Koppehele**, Fairfield; **James J. Gardner**, Hamilton, both of Ohio

[73] Assignee: **Fluid Kinetics, Inc.**, Fairfield, Ohio

[21] Appl. No.: **156,222**

[22] Filed: **Jun. 3, 1980**

[51] **Int. Cl.³** **B05B 7/06**

[52] **U.S. Cl.** **239/424; 239/524**

[58] **Field of Search** 239/416, 404, 420, 424, 239/102, 524, 422, 423, 426, 427.3, 427.5

[56] **References Cited**

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4,018,387	4/1977	Erb et al	239/405

FOREIGN PATENT DOCUMENTS

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1545284	5/1979	United Kingdom	239/422 X
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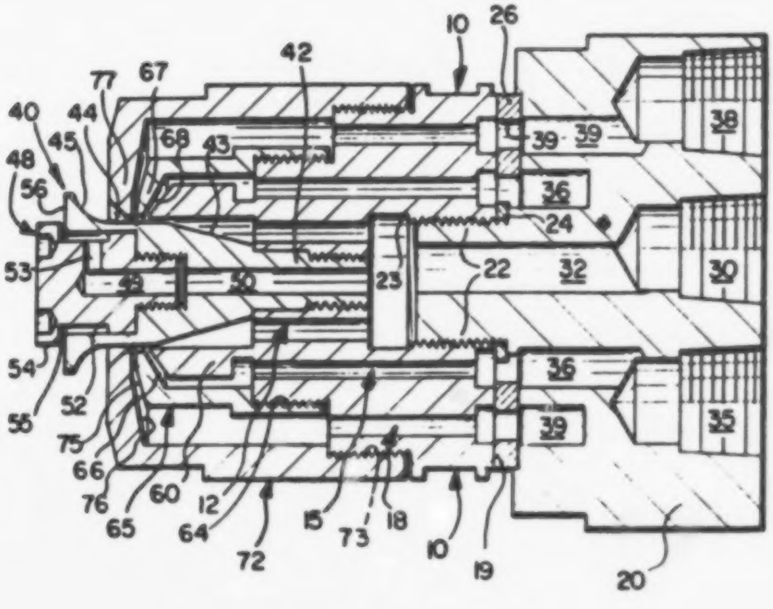
Primary Examiner—Andres Kashnikow
Assistant Examiner—Gene A. Church
Attorney, Agent, or Firm—Biebel, French & Nauman

[57] ABSTRACT

A mixing and atomizing nozzle is disclosed which has a first or inner orifice which directs a thin film of gas outwardly and expands the same to supersonic speed for subsequent transition to subsonic speed over a deflector member or mandrel, together with first and second orifices which are positioned adjacent each other and immediately outwardly of the first orifice for applying thin films of first and second liquids for mixing and atomization.

3 Claims, 2 Drawing Figures



% INCREASE IN CdA_0 vs. lbs. SOLID DISCHARGED

FIGURE 24 - GRAPH OF EROSION TEST vs MASS FLOW IN FLO-SONICS ATOMIZER

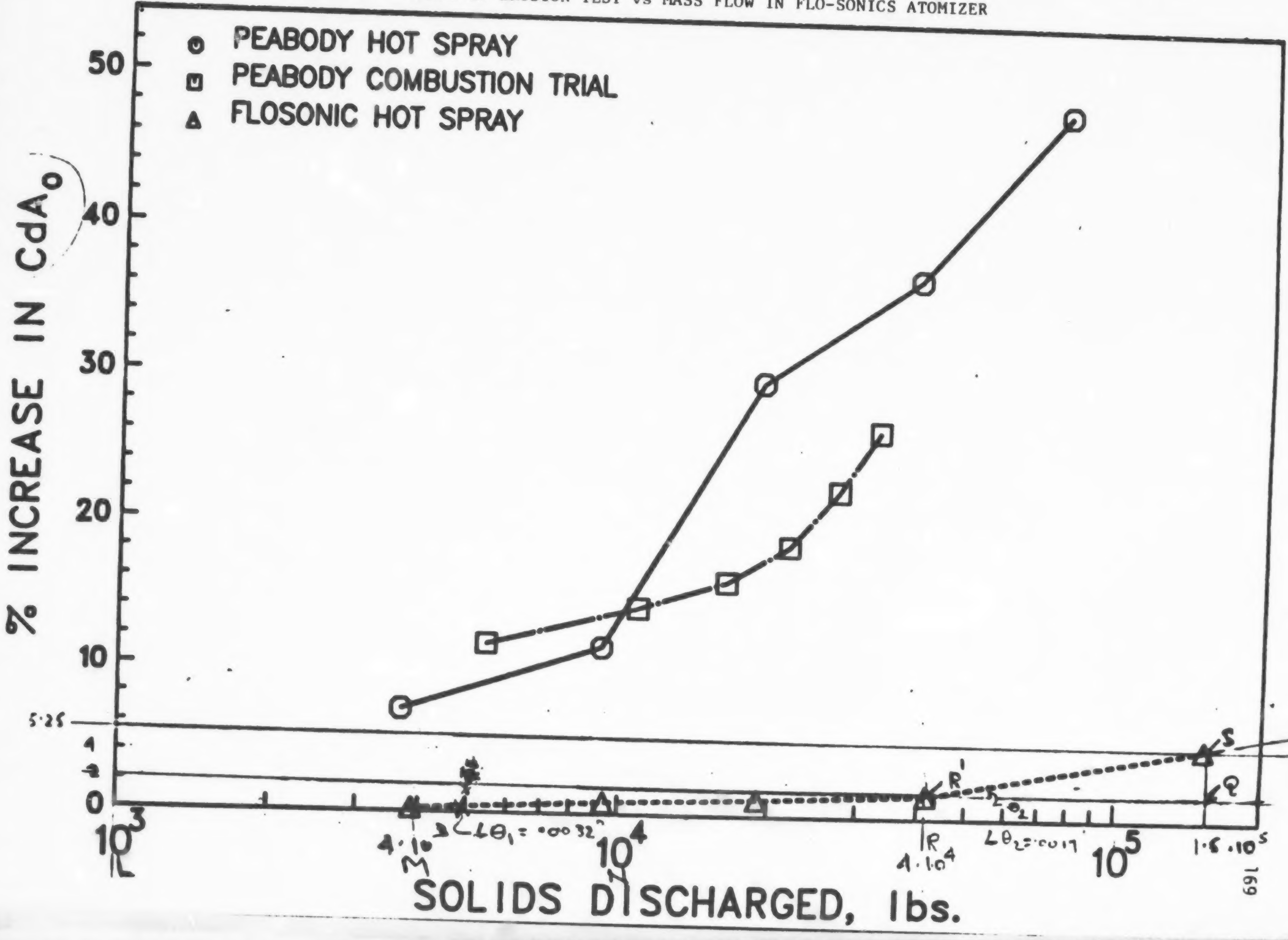
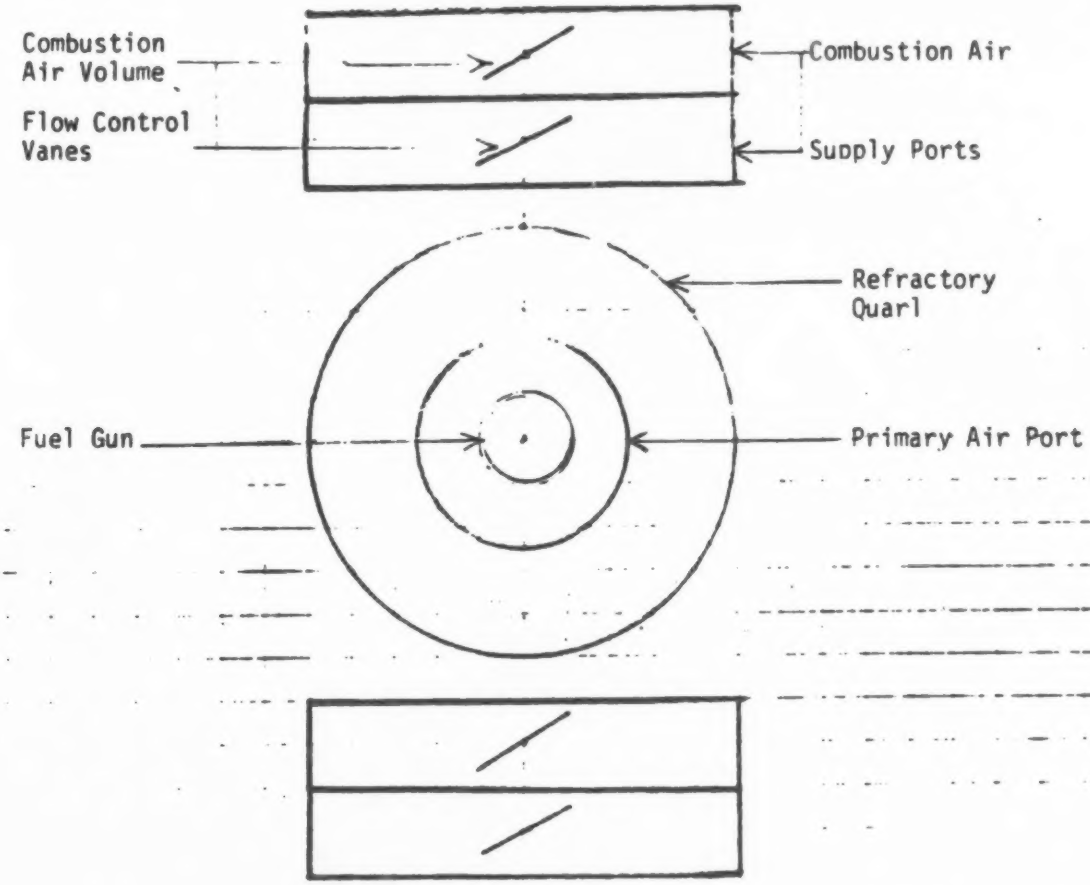


FIGURE 25

General Burner Arrangement - Front Elevation


Combustion Air Volume
Flow Control Vanes
Combustion Air
Supply Ports
Refractory Quarl
Fuel Gun
Primary Air Port

NOTES

1) Quarl Refractory - 3200^{0} F. Fusion Point

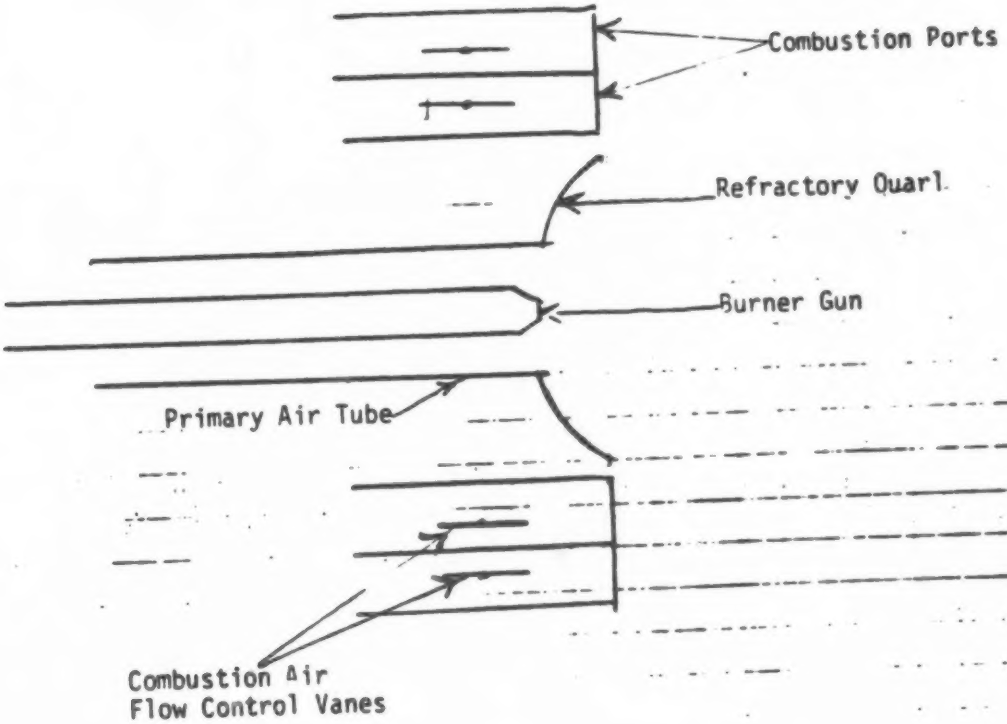
2) Fuel Ash 2100^{0} FTA (Reducing Atmosphere)

3) Estimated Dimensions (R.G.)

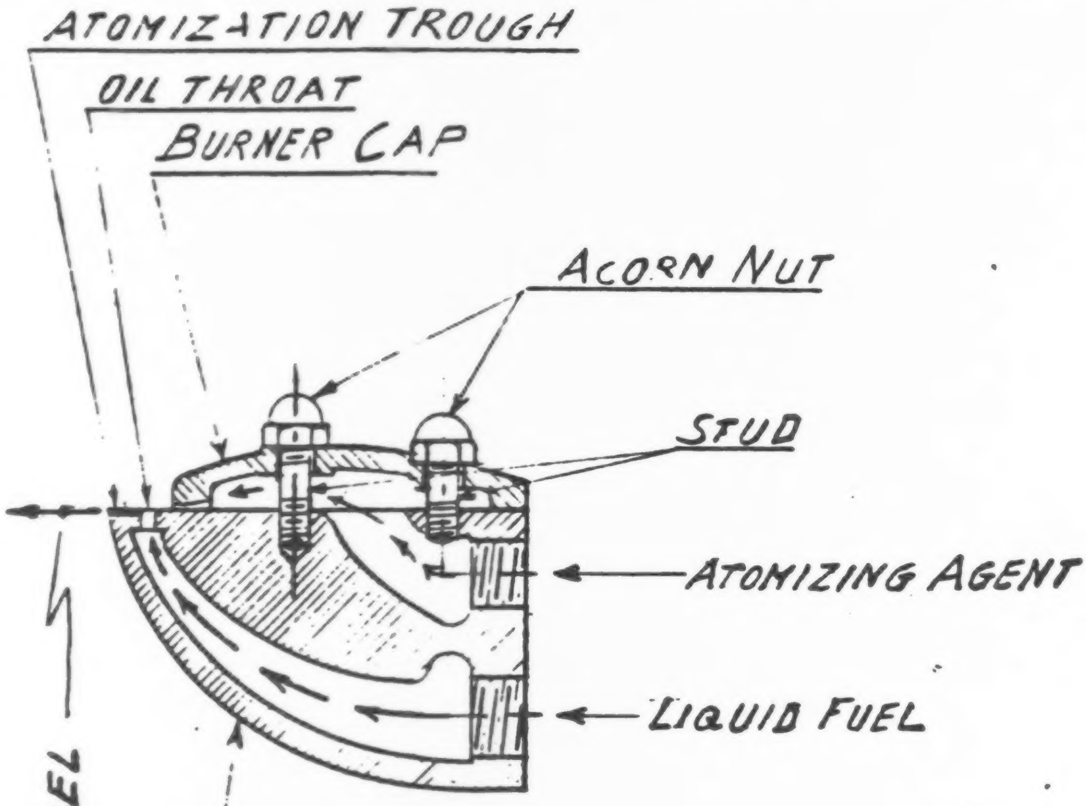
Dia. of Quarl	8" - 12"
Depth of Quarl	4" - 6"
Dia. of Primary Air Tube	4"
Dia. of Gun Tube	2"

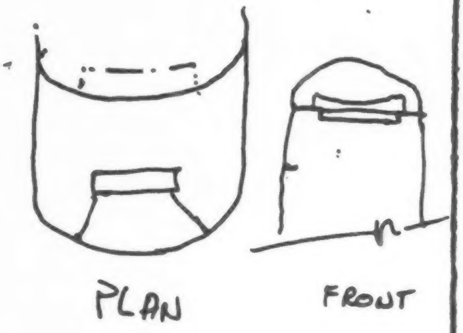
FIGURE 25.1

Schematic Arrangement - Longitudinal Section


Combustion Ports
Refractory Quarl
Burner Gun
Primary Air Tube
Combustion Air
Flow Control Vanes

213905


ATOMIZATION TROUGH
OIL THROAT
BURNER CAP
ACORN NUT
STUD
ATOMIZING AGENT
LIQUID FUEL
ATOMIZED FUEL
BURNER BODY



CALOREX

SERIES "50" BURNERS

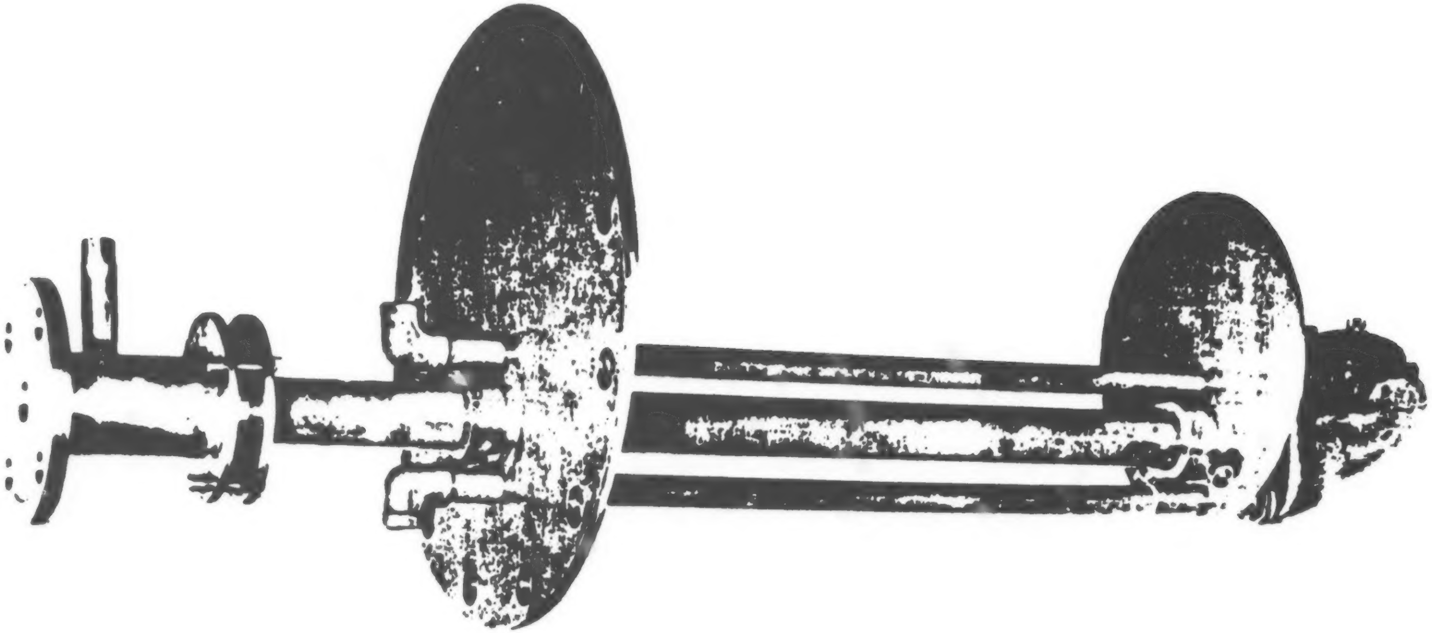
W. N. BEST COMBUSTION EQUIPMENT CO., INC.

FIG. 26 Sectional Elevation W.N. Best "LIP" Burner

52 J FLAT FLAME ATOMIZER

With jacket for - heating in sulfur furnace
- cooling in glass furnace
- heating in spent acid reclaimer

FIG. 26.1 General Arrangement "LIP" Burner for High Temperature Application



W.N. BEST COMBUSTION EQUIPMENT CO., INC.
SINCE [illegible] SPECIALISTS IN COMBUSTION FUEL FIRING SYSTEMS
11 SOUTH STREET, DANBURY, CONN. 06810
A DIVISION OF PREFERRED UTILITIES MANUFACTURING CORPORATION

W N BEST COMBUSTION EQUIPMENT CO INC
SINCE 1890 SPECIALISTS IN COMBUSTION FUEL FIRING SYSTEM
11 SOUTH STREET DANBURY CONN 06810
A DIVISION OF PREFERRED UTILITIES MANUFACTURING [illegible]

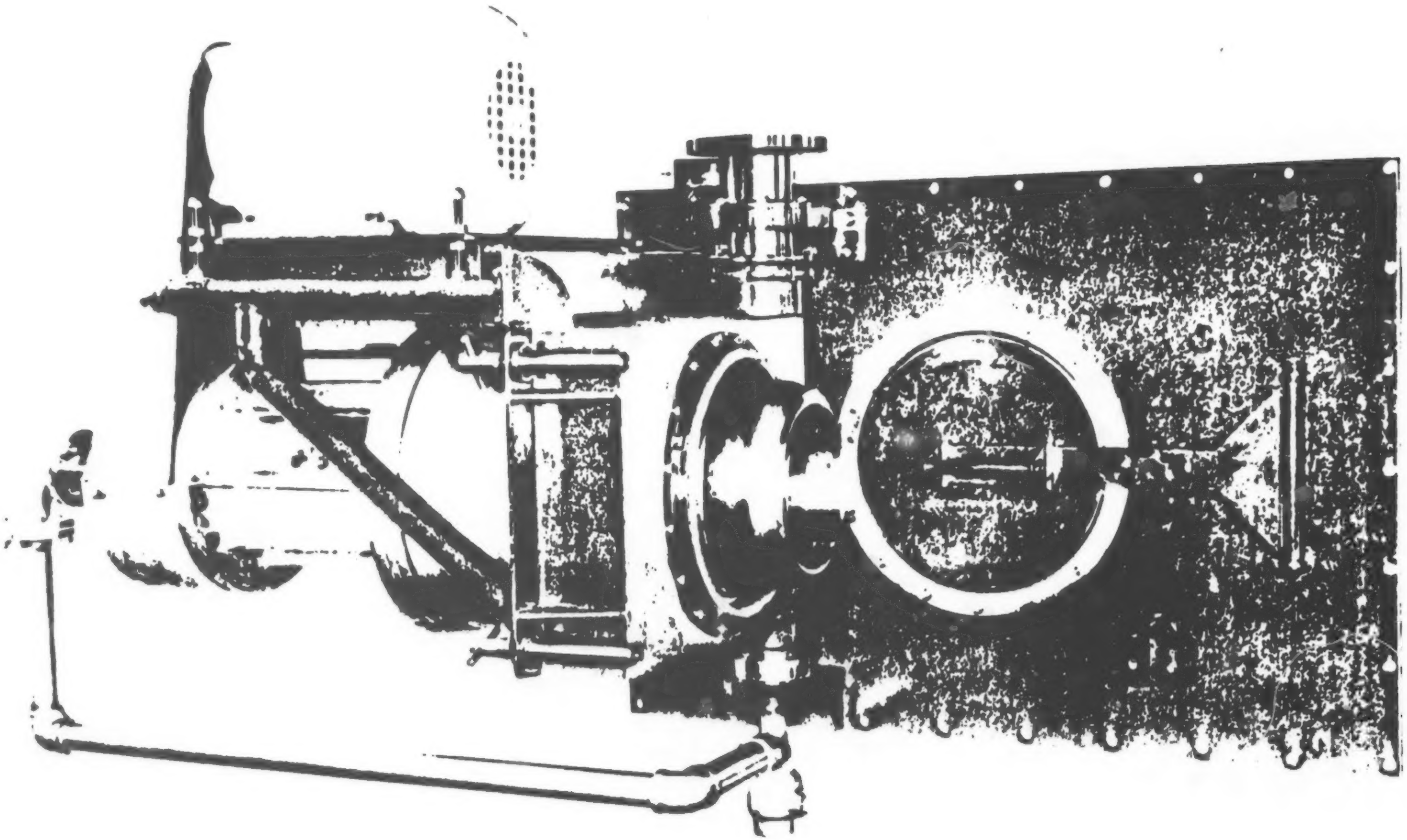
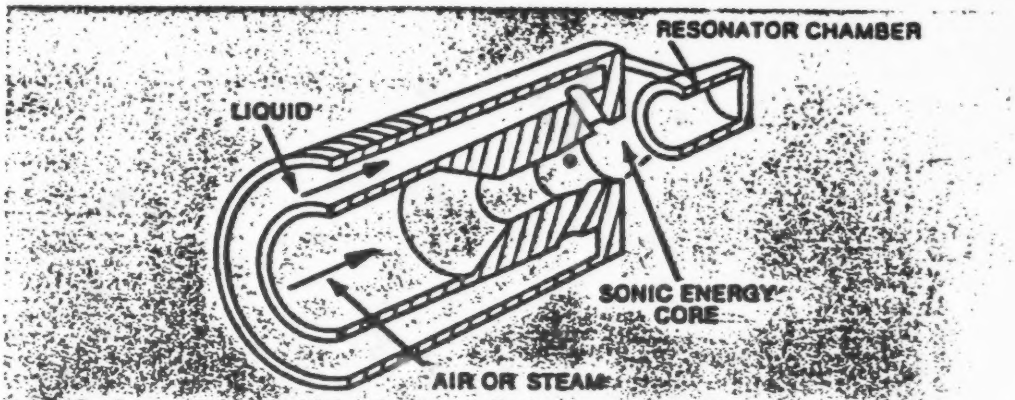


FIG. 26.2 General Arrangement
50,000 lbs./hr Spent Acid
Atomizer - Rotary

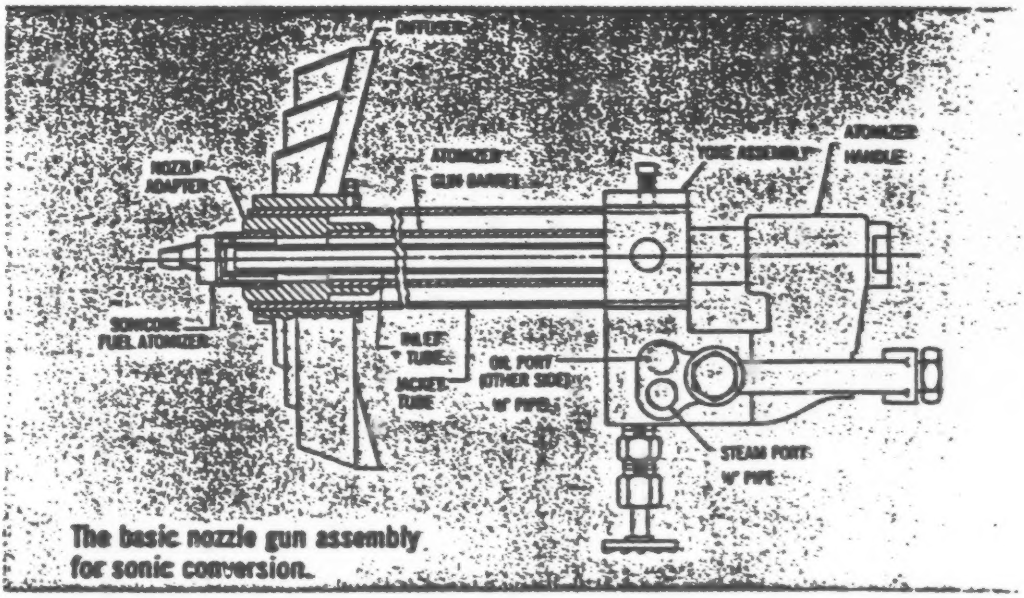
AS-50M SPENT ACID ATOMIZER

Capacity: 50,000 lbs./hr.

Fig. 27

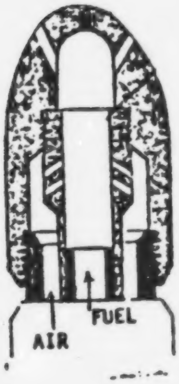

RESONATOR CHAMBER
LIQUID
SONIC ENERGY CORE
AIR OR STEAM

Sonic atomizer uses high velocity gas flow to create a standing sonic shockwave. Pressurized gas flows through a convergent-divergent nozzle into a resonator chamber at supersonic velocities. As the air is reflected from the resonator, it creates a standing shock wave between the cavity and the body of the nozzle. Liquids pumped into the shockwave are vigorously sheared into fine droplets.


DIFFUSER
NOZZLE ADAPTER
ATOMIZER GUN BARREL
YOKE ASSEMBLY
ATOMIZER HANDLE
SONICORE FUEL ATOMIZER
INLET TUBE
JACKET TUBE
OIL PORT (OTHER SIDE) ½" PIPE
STEAM PORT ½" PIPE

The basic nozzle gun assembly for sonic conversion.

Fig. 27.1



(c) Peabody

Figure no. 28

Appendix No. 1

Use of CWM in Urquhart Vortex Cup Atomizer

Flowtime; Heat absorption; Fluid Thickness at Atomizing Shear Point - 200.10^6 Btu/Hr

(See Page 6 for Summary of Data)

		Input
1.	Capacity of atomizer is proportional to area of Vortex Cup.	
2.	A 1 1/2" Ø Urquhart cup has atomizing capability for 25.10^6Btu/Hr.	1 1/2" Ø = 25.10^6 Btu/Hr.
3.	Therefore, the required dia. for $200.10^6 = \frac{d_o^2}{d_1^2} = \frac{25.10^6}{200.10^6}$	
	$d_1^2 = \frac{200}{25} \cdot d_o^2$	
	$d_o = 1.5" \therefore$	
	$d_1 = \sqrt{\frac{200}{25}} \times 1.5$ =	4.25" Ø = 200.10^6 Btu/Hr.
4.	Area d_1 (200.10^6Btu/Hr.) =	14.2 sq. ins.
5.	C.V. of CWM per Imp. gal. (70/30 - 13,000 Btu coal)	108.563 Btu
6.	Imp. gals. flow per sec. @ 200.10^6 Btu/Hr. Input is:	
	$\frac{200.10^6}{3600 \times 108,563} = \frac{1842}{3600}$	0.51 Imp.gal./ sec.
7.	Vol. Flow Ft.^{3} Sec^{-1} = $\frac{0.51}{6.24}$ = =	0.082 ft.^{3}sec^{-1} 142 in.^{3}sec.$^{-1}$
8.	Radius, ft. centre line of oil tube to Oce. = $\frac{4.25}{2 \times 12}$ =	0.177 ft.
9.	Time of flow to cup rim said to be milliseconds (Peter Nutcher).	

10. Assume t = .01 sec. (10 milliseconds)

Then Velocity across Vortex cup is

$\frac{0.177}{.01}$ = 17.7 ft. sec.$^{-1}$ (say) -------------------------- 18 ft. sec.$^{-1}$ (fps)

11. Theoretical fluid head to create this velocity

$$h_1 = \frac{V^2}{2g}$$

$$h_1 = \frac{P \times 144}{p} = \frac{P \times 144}{62.4 \times 1.193} = 1.934P$$

$\therefore$ P = $\frac{V^2}{1.934 \cdot 64.4}$ = -------------------- $\frac{V^2}{124.5}$

12. Therefore for a Velocity of 18 fps (item 10)

P (PSI) = $\frac{18^2}{124.5}$ --- = 2.60 psi

12.1 It is conceivable that the effect of the steam vortex (See Fig. 3.1) could create such a back pressure on the atomizing cup.

13. If the time frame from centre line of oil tube to cup rim (See Fig. 3) had been assumed to be 0.1 sec. (instead of 0.01 sec.)
then V would be 180 fps
and P would be $\frac{(180)^2}{124.5}$ = 260 psi.

which is highly improbable

14. Cup area is 14.2 sq. ins.
Vol. flow is .511 Imp. gal/sec.
= .082 ft.^{3}sec.$^{-1}$
= 142 in.^{3}sec.$^{-1}$
= 1.42 in.^{3} in.01 sec.

15. Therefore fluid film thichness is

$\frac{1.42}{14.2}$ -- = 0.10 inch at shearing rim of cup

16. This thin film is subject to radiant heat transfer from the flame front.

16.1 Consider the amount of heat absorbed and the resulting effect on the consistency of the CWM at the vortex cup rim (shearing point).

17. Equation for radiant heat transfer is:

$Q_r = \partial eA\ (T_1^4 - T_2^4)$ Btu/Hr.

where:

∂ = Boltzman constant = $0.174.10^{-8}$ Btu/Hr per sq. ft.

e = emissivity factor = 0.875 (assumed)

A = cup area = 14.2 sq. ins. = 0.1 sq. ft. (rounded)

T_1= Flame front temp. = 2400°F or 2860°R. (assumed)

T_2= CWM temp. = 212°F = 672°R (assumed)

Then

$$Q_r = 0.179.10^{-8} \times 0.875 \times 0.10\ (2860^4 - 672^4)$$

$$= 15.10^{-11}\ (6.7.10^{13} - 2.04.10^{11})$$

$$= 15.10^{-11} \times 10^{11}\ (668)$$

Q_r = 10,020 Btu/Hr.

$Q_r = \frac{10,020}{360 \times .01}$ = -- .03 Btu in .01 sec.

18. C_p of coal = .25

C_p of water = 1.0

18.1 Vol. in .01 sec. $\left(\frac{\text{Item 7}}{100}\right)$ = 1.42 in.^{3}

18.2 Weight of 1.42 in.^3 of CWM is

$$\frac{1.42}{1728} \times 62.4 \times 1.193 \text{ ---------------- } = .0612 \text{ lb (flow in .01 sec.)}$$

70% Coal content weighs .7 x .0612 = 0.043 lb.

30% water content weighs .3 x .0612 = 0.0184 lb.

19. Av. C_p per lb. CWM is:

$$\left\{(0.7 \times 0.25) + (0.3 \times 1)\right\} = .475 \text{ Btu/lb/}^{\circ}\text{F}$$

20. Heat absorbed by .0612 lb. CWM is 0.03 Btu in .01 sec. (Item 17)

20.1 Temp. rise is obtained from Equation

$$Q = W.C_p \Delta T, \text{ whence } \Delta T = \frac{Q}{W.C_p}$$

Subst. $Q = 0.03$; $C_p = .475$; $W = .0612$, we obtain

$$\Delta T = \frac{0.03}{0.0612 \times 0.475} = 1.032^{\circ} \text{ (F or R)}$$

21. Enthalpy increase in water content of CWM in .01 sec. is
0.0184 (Item 18.2) x 1.032 = ---------------------------------- .02 Btu

22. Heat of vaporization of .0184 lb. water at temp. of 212°F is:
970.4 x 0.0184 = -- 18 Btu

23. .˙. amount of water evaporated is:
$\frac{.02}{18}$ = -- .001 lb.

24. Lb. water remaining is .0184 - .001 = ---------------------------- .0174 lb.

25. % water evaporated is $\frac{.001}{.0184}$ = ---------------------------- 5.4%

26.	Rim weight of CWM is now .043 plus .0174 = --------------------------	.0604 lb.
	Percentages by weight are now:	
	Coal = $\frac{.043}{.0604}$ = --	71%
	Water = $\frac{.0174}{.0604}$ = --	29%
	i.e.: CWM is now a 71:29 mix by weight.	
27.	THEREFORE: Radiant heat absorption has negligible effect on CWM ratio.	

SUMMARY OF RESULTS OF CALCULATIONS of Flow time versus: CWM fluid thickness at atomizing rim; heat absorbed; temp. rise.

1.	Flow time	0.01 sec.
2.	Film Thickness at rim	0.10 inch
3.	Heat absorbed	0.03 Btu
4.	Temp. rise in fluid	1.032°F
5.	Vol. @ fuel rate of 75.10^6 Btu/Hr	11 fps

(compare 5 to item 10 where velocity at $200 \cdot 10^6$ Btu/Hr. is 18 fps).

Appendix No. 2

Suggested Program of Research

COM - COW - CWM

10-10-82

1. Rheograms from existing suppliers - e.g.

Cape Breton Development Corp. (C.B.D.C.) (Carbogel) - Halifax, N.S.
Atlantic Research Corp. (ARC - Coal - Alexandria, Va.
Atlantic Richfield Petroleum Products Co. - Harvey, Ill.
Gulf & Western- Advanced Fuel Technology Div. - New Jersey
Scotia - Liquicoal - Halifax, N. S.
Occidental Research (COM Energy Co.) - Jacksonville, Fla.
Slurry Technologies - Miami, Fla.
Comco - Pittsburgh, Pa.

1.1 If viscosity in rheograms is shown in terms of dynes cm^{-2}, derive the conversion factor to centipoise from geometry of Brookfield (or other) rotary spindle viscosimeter at given shear rate or spindle speed.

1.2 Or preferably derive vis. in centipoise or SSU from ΔP obtained from test loops, giving ΔP versus Pipe 0 and flow rate.

1.3 Vis. values so obtained can then be used in the Darcy or Poiseuille equation where ΔP versus length, dia., flow, and Reynolds numbers are interrelated - Vis:

Darcy Equation: $\Delta P = \frac{pf.Lv^2}{144D^2g}$

Poiseuille Equation (laminar flow): $\Delta P = \frac{0.000668\mu lv}{d^2}$

2. Atomizing force and atomizing fluid quantity for a given viscosity of CLM versus the fuel film thickness at the shear edge.

2.1 Resultant droplet size range and distribution for a given design of atomizer.

2.2 Type of atomizing fluids.

.../2

3. Design factors affecting fuel distribution pattern for various viscosities.

4. Required ignitor capacities for various fuel rates.

5. Flame stability as a function of:

   .1 Previous preheat of fuel
   .2 Auxiliary fuel support
   .3 Swirl number
   .4 % V.M.
   .5 Combustion Air Temperature.
   .6 % O_2.

6. % Carbon burn-out as a function of:

   .1 % V.M.
   .2 Swirl No.
   .3 % O_2
   .4 Products of combustion recirculation.
   .5 Combustion air temp.

7. CWM physical and chemical characteristics based on:

   a) Beneficiation
   b) Agglomeration
   c) Oil film thickness
   d) Dispersants
   e) Residual % ash after - a) grinding to 200 mesh
      b) beneficiation process.
   f) Residual % sulphur after - a) grinding to 200 mesh
      b) beneficiation process.
   g) Hardness of coal particles (crystal structure)
      1) in parent coal
      2) after grinding to 200 mesh
      3) after beneficiation (spherical agglomeration)

.../3

h) Hardness of ash particles:
  1) as per item 7 (g).
  2) related to chemical composition.

8. Combustion efficiency

8.1 In many cases the requirements for atomization, ignition and flame stability have been established on a qualitative basis.

8.2 Quantitative factors, however, are meager.

8.3 It seems essential now to determine combustion efficiency of a select group of burner "systems" i.e.: the entire burner including atomizer and combustion air register with positionable vanes.

8.4 The combustion efficiency numbers should relate %.O_2 and % carbon-out against the quantitive factors of:

.1 Atomizing fluid type
.2 Atomizing fluid pressure
.3 Atomizing fluid mass flow/lb. fuel.
.4 Firing rate.
.5 Combustion air temperature
.6 Swirl number
.7 CWM basic (non-proprietary) data on viscosity versus flow rate and atomizer fuel passage velocities (shear rates); % V.M; temperature and (if possible) analysis of the mother coal and its ash content.

9. There would be the further need of determining the burner overall design and its ability to control flame dimensions, including numerical data on wind box pressure range and combustion air temperature, - in relation to (a) oil designed furnace dimensions,
(b) coal designed furnace dimensions.

.../4

10. The question of atomizer life is becoming more apparent as a function of metallurgy versus replacement cost.

11. Optimization of atomizer designs for max. life seems to fall in a basic pattern (I will write on this in a future report).

12. Possibility of chemical (or additive) means of reducing CWM coal and ash particle hardness.

Appendix No. 3

Fuel Velocities in Forney CWM Atomizer as per design of Fig 12 @ Firing Rate of 40.10^6 Btu/Hr.

1.	Cap of burner with areas as shown on Figure 12.	40.10^6 Btu/Hr.
2.	U.S. gph flow with 70/30 CWM $\frac{40.10^6}{90,493} = 442$ USgph =	442 USgph 4392 lbs/Hr.
3.	Flow of CWM in $ft^3sec^{-1} = \frac{442 \times 8.33 \times 1.11}{69.26 \times 3600}$ =	$.0164\ ft^3sec^{-1}$ (CWM)
4.	Fuel Inlet area (Total) $= \frac{.131}{144} = .00091\ ft^2$	
5.	Fuel velocity through supply tubes = $\frac{.0164}{.00091}$ =	18 fps
6.	Atom. air flow is: .25 lb @ 50 PSI/lb. fuel (Est. mix. chamber press.)	
6.1	Density of atom. air at 50 psi @ $60^{o}F$ is $\frac{50 + 14.7}{14.7} \times .076 = 0.334\ lb/ft^3$.	
6.2	Vol. of atom. air per lb. fuel = $\frac{0.25}{0.334} = .75\ ft^3$	
6.3	Vol. of atom. air for 442 USgph rate per sec. $= \frac{442 \times 8.33 \times 1.193 \times .75}{3600} =$	$0.915\ ft^3sec^{-1}$ @ 50 psi Est. mix. chamber press.
7.	Vol. of emulsion of Atom. Air plus fuel is: $(.0164 + .915) = .93\ ft.^3sec^{-1}$	$.93\ ft^3sec^{-1}$ Vol. of total emulsion

.../4

8.	Area of exit annulus (Given by Forney) is: $\frac{.3527}{144} = .00245 \text{ ft}^2$	
9.	Velocity, fps, of emulsion is: $\frac{.93}{.00245}$	380 fps (emulsion)
10.	Erosion index ratio is: $\frac{.0164}{.93}$	.0176 Fuel/Emulsion ratio
11.	Angle of attack of emulsion assumed 45°, sin 45° = .707	
11.1	Inverse Sin 45° = $\frac{1}{.707}$ = 1.41	
12.	∴ Total erosion index no. is (380 x .0176) + 1.41	8

21-12-82

APPENDIX NO.4

EXTRAPOLATION FROM NRC GRAPH OF "% INCREASE IN CdAo VS LBS. SOLIDS DISCHARGED" - REFER FIG. 24-A4 (attached)

I. 1. Base line LN for 1 order of magnitude (i.e. x 10) =10.5[(1)] units of graph length

2. Line segment LM has a value of ------------6.3 units

Ratio to 1 power of graph length is $\frac{6.3}{10.5} = .6$ = log of number at scale length 6.3

This number is then $10^{.6} = 4$ (rounded value)

3. Line segment LN has a value of 10 (times)

4. Line segment NR has a value of 6.3 scale (RG) units = LM

$\therefore$ number value of N = 4.10^4

5. Linear value of line segment MR = $4.10^4 - 4.10^3 =$
$10^3\ (40-4) = 36{,}000$ scale units

Value of ordinate $RR^1 = 2$

$\therefore$ slope of line MR = $\frac{2}{36{,}000} = \underline{\underline{.000055}} = \tan \angle .0032^\circ$ (2)

II. Now determine slope of line R^1S

Line segment R^1Q has scale length units of 1.9

$\therefore$ power value is $\frac{1.9}{10.5} = .18$ = log of value at point Q

---

(1) As measured by R.G. scale.

(2) Angle shown in graph is not true geometry.

.../2

6. Value of quantity at point Q is then $10^{.18} = 1.5.10^5$ lbs.

(= 16,222 US gals at Sp.G. of 1.11)

Linear value of line segment R^1Q

$= 1.5.10^5 - 4.10^4 = 10^4\ (15-4) = 110,000$

Value of ordinate QS = (5.25 - 2) = 3.25

Slope of R^1S is then: $\frac{3.25}{110,000} = \underline{\underline{.00003}} \doteq \tan \angle .0017^\circ$

7. Therefore, after a discharge of 40,000 lbs. or approx. 4326 USgals the rate of erosion is reduced by $\frac{.000055 - .000030}{.000055} = 45\%$

8. At a flowing rate of 1.35 USgpm or 81 US gph the time internal to the point of 45% reduction in erosion rate is $\frac{4326}{81} = 53$ hrs.

9. The NRC chart ends at a discharge value of 150,000 lbs.or 16,222 USgals.

9.1 The time interval is $\frac{16,222}{81} = 200$ hours (The intended test duration)

III By extrapolation from the foregoing data, determine the % CdA increase at 1000 Hrs

10. Fuel quantity is 1000 x 81 = 81,000 gals

= 81,000 x 8.33 x 1.11 = 748,950 lbs.

11. Starting pt. of curve is point R^1 at 40,000 lbs.

11.1 Then units of base length is (748,950 - 40,000) = 708,950

11.2 Now assume that slope of R^1S will continue at the value of tan $.0017^\circ$ $= 3.10^{-5}$

Let X = ordinate at abscissae value of 708,950

Then $\frac{X}{708950} = 3.10^{-5}$

X = 21.27

I.E. the value of CdA at 1000 Hrs. will be 21.27%

.../3

12. The question then is: at what point in time must the atomizer be rejected?

12.1 N.B. It must be considered that the rate of increase of CdA may become less (or more?) than the value $\underline{3.10^{-5}}$.

13. Consider % CDA at 500 hours.

13.1 Flow value = 500 x 81 = 40,500 U.S. gals.
= 375,000 lbs. (rounded).

13.2 Curve slope (ref. item 6) is tan $\angle$ .0017 = 3.10^{-5}

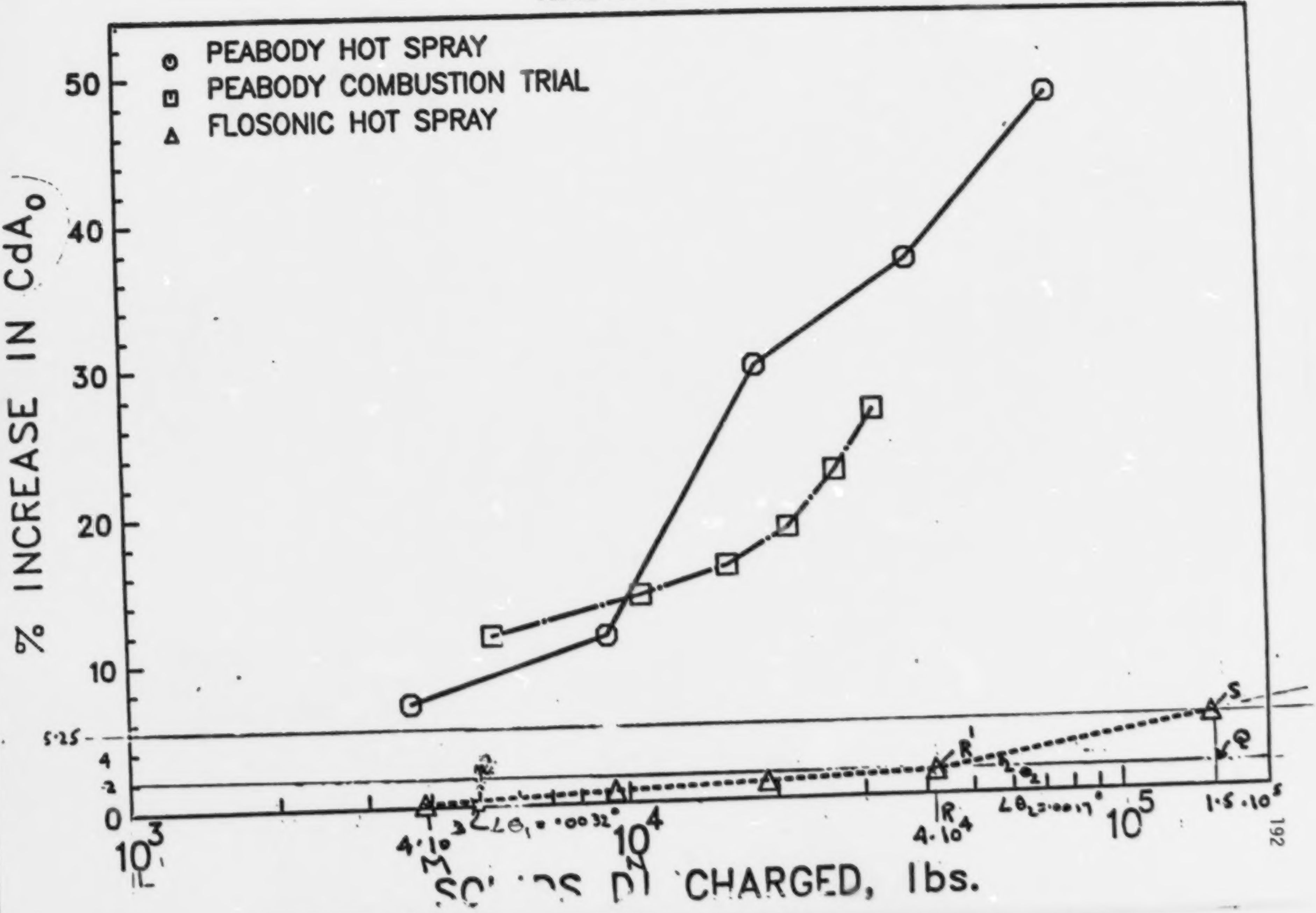
13.3 Let X = ordinate at abscissae point of 375,000 lbs.

Then $$\frac{X}{(375{,}000 - 40{,}000)} = 3.10^{-5}$$

X = % CDA of 11.25%
(after 500 hours. operation @ 81.45 gph)

% INCREASE IN CdA$_0$ s. lbs. SOLID DISCHARGED

FIGURE NO. 24 - A4



APPENDIX NO. 5

ATOM. AIR AND FUEL FLOW - VELOCITIES AND VOLUME

NRC FLO-SONICS ATOMIZER

DATE: 2-1-83

1. Reference Fig. No. 21 (Section "Figures") extracted from Atlantic Research Laboratory Technical Report No. 33 (NRCC 11916) entitled:

"Nozzles for Burning CLM
1. Abrasion of Ceramic Modified Flo-Sonic Nozzle, Using a Hot-Spray Test Loop".

2. The dimensional and capacity data of the atomizer, used in the following calculations were provided by Mr. Kevin Jonnaison, Chemical Engineer, NRC.

3. Av. firing rate during 200 hour test: $1.5.10^{6}$ lbs.
= 16222 US gals/ (200 x 60) = ---------------------------------- 1.35 USgpm

4. Fuel fired was a COW mix of:
55% high bituminous coal, 15% water, 30% #6 oil, having an ash content of 1.5%.

4.1 The parent coal was from C.B.D.C. (N.S.) and was beneficiated by the NRC spherical agglomeration process.

5. Approx. Sp. G. is --- 1.11

6. Flow rate of fuel in cfs is:

$$\frac{1.35 \times 8.33 \times 1.11}{62.4 \times 1.11 \times 60} = \text{---------------------} \quad 0.003 \text{ cfs}$$

7. Fuel pressure --- 115 psig

8. Atomizing air pressure --- 100 psig

9. Atomizing air flow is sonic and volume flow Q is obtained from the equation

$$Q = YC\sqrt{\frac{2g \times 144\,\Delta P}{\rho}} \times A^{1)} \text{-----------------------------} (1)$$

---

1) Crane "Flow of Fluids" Technical Paper No. 410 Page 2-14.

.../2

10. Critical pressure ratio for sonic velocity is .53 P_1^1 ∴ Nozzle throat pressure Pt = a max. of 114.7 x .53 ---------------------- 60.8 psia.

10.1 Max ΔP is then 114.7 - 60.8 = ---------------------------------- 54 psi

Y = Expansion factor = .70 (Crane - P.A20 with k factor for air at 1.4 and $\frac{d_o}{d_1}$ estimated at $< .2$

C = Nozzle coeff. for $\frac{d_o}{d_1} < .2$ = .98 with turbulent flow (Crane - P.A19)

p = air density of flowing conditions at Pt_1 (atom. air nozzle throat = $\frac{60.8}{14.7}$ x .076 = ---------------------------------- 0.314 lb./cu. ft.

A = Effective area of atomizing air annulus, sq.ft.

Q = vol. flow/sec. at flowing conditions. (See Item 9 above) Tech. Report #33 states atom. air flow is 25 SCFM

Then at flowing conditions in throat at Pt_1 the volume of atomizing air is: $\frac{25}{60} \times \frac{14.7}{60.8}$ = ---------------------------- 0.10 cfs

$$A = \frac{0.10}{0.7 \times .98 \times 2 \times \sqrt{\frac{32.2 \times 54 \times 144}{0.314}}}$$

$$= \frac{0.10}{.69 \times (1263)} = \text{--------------------} \quad .000115 \text{ sq.ft.}$$

↳ Approx. sonic value)

= .0165 sq.in

11. Let X = Atom. air Annulus width (tentative - see Item 21)

Dia. of annulus is approx.I.D.of Cap nut (Gap A-Fig.2.2) then atom. air annulus width, in ins. is

$\pi \times .930 \times X = .0165$

$X = \frac{.0165}{\pi \times .930}$ - -- .00565 inch

12. To increase atom. air flow

- a) increase annulus width,
- b) (or) raise pressure.

To decrease atom. air flow decrease pressure.

12.1 N.B. Min. throat pressure versus atmos. pressure =

$$\frac{14.7}{.53} = 27.7 \text{ psia}$$

∴ min. applied pressure for NOZZLE Discharge

$$\frac{27.7}{.53} = \text{-----------------------------(at } Pt_2 \text{ - Gap A)} = 52.3 \text{ psia} = 37.6 \text{ psig}$$

13. The value of 25 SCFM as per Technical Report No. 33(2) is adequate for max. flow of fuel of 2.3 USgpm for a ratio of

(25 x .0764) / (2.3 x 8.33 x 1.11)

= 1.91 /21.27

= .09 lb. atom. air/lb fuel

13.1 It should be noted that this figure compares to that of other air atomizing burners as follows (from Tables 1 & 1A of Report)

Hauck - 1.5 psi ------------.20 lb. /lb.
Urquhart "Vortex Cup" - 150 psi - .15 lb/lb.
Atlantic Research - 30 psi -------.3 to .5 lb/lb.
Forney - 70 psi ----------.25 lb/lbs.

13.2 If the mean value for the 200 hr. test of 1.8 US gpm 2) is taken, then the atom. air/fuel ratio is

$$\frac{.09 \times 2.3}{1.8} = .115 \text{ lb/lbs fuel}$$

---

2) Table III P.10 of Tech. Report No. 33 (See Item 1).

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14.	If the mean discharge value of 1.3 USgpm, obtained from the NRC chart, (attached to Appendix 4) is taken) the atom. air/fuel ratio is: $\frac{.09 \times 2.3}{1.35} = \underline{.15 \text{ lb/lb. fuel}}$ (Same ratio as in the Urquhart "Vortex Cup".)	
15.	Width of exit Gap A is --	0.415 ins.
16.	Mean dia. of gap A is I.D.of Cap nut - $\frac{.0415}{2} \times 2 = 0.930 - 0.415 =$ ---------------	0.89 ins.
16.1	Area of exit Gap A, sq. ft., is: $\frac{\pi \times 0.89 \times .0415}{144} =$ ------------------------------------	8.10^{-4} sq.ft.
17.	Volume flow cfs, through Cap A is: .003 (item 6) + 0.10 (Item 10.1) = ----------------------	0.103 cfs
18.	Velocity through Gap A (no allowance for air expansion) $\frac{0.103}{8.10^{-4}} =$ ----------------------------------	1) 525 fps
19.	However, if press. at Pt_1 of atom. air nozzle is 60.8 psia and max. sonic flow press. in Gap A Pt_2 is $\frac{14.7}{.53} = 27.7$ psig $= Pt_2$	
19.1	Then expansion ratio is $\frac{60.8}{27.7} = 2.2$ ---	2.2
20.	Now width ratio between Pt_2 and Pt_1 $= \frac{\overset{\text{Pt}_2\text{ (item 15)}}{.0415}}{\underset{\text{Pt}_1\text{ (item 11)}}{.00565}} = 7.34$	
21.	.˙. one could consider that width of Gap A occupied by the atom. air jet stream is 2.2 x .00565 = -----------------------------	0.124 in.

---

1) See alternative calculation in the following

.../5

22.	Therefore portion of Gap A width for fuel flow is 0.415 - .0124 =	.0291 in.
23.	Now assume that 25% of atom. air from Pt_1 is used to combine with fuel to cause its acceleration, then:	
.	Vol. of atom. air under flowing conditions in Gap A i.e. point Pt_2 = .10 x 2.2 = $\underline{.22\text{ cfs}}$ (total atom. air) ------------------	122 cfs arom. air
24.	.˙. Vol. of fuel + 25% of atom. air flowing through Gap A is: .003 + (.22 x .25) = (.003 + .055) = .058 cfs emulsion flow	$\underline{.058\text{ cfs}}$ @ 27.7 psia press.at Pt_2 See Fig.2.2
25.	Available area of Gap A for Emulsion flow, sq. ft., is: $\frac{\pi \times 0.89 \times .0291}{144}$ = ----------------------------------- =	$5.6 . 10^{-4}$ sq.ft 70% Gap A
26.	Velocity of emulsion flow is: $\frac{.058}{5.6 \times 10^{-4}}$ = --	103.6 fps
27.	Ratio fuel to atom. air entrained is: $\frac{.003}{.055}$ = --	.0545
28.	.˙. Erosion velocity index is: $(103.6 \times .0545) + (\sin^{-1} 45^{\circ}) = 5.65 \quad 1.41 =$ -------------	7.06 fps

APPENDIX 6

FUEL VELOCITIES IN NORTH AMERICAN ATOMIZERS

Bulletin 56.42 - Full Emulsion Atomizer

1.	Exit port area per 500 US gph	1 sq.in.
2.	Max. (present) capacity	400 USgph
3.	Exit port area $\frac{400}{500}$ =	.80 sq.in.
4.	Flow per sec. of CWM in cu. ft. is: $\frac{400 \times 8.33 \times 1.11}{62.4 \times 1.11 \times 3600}$ = --------	.015 cfs
5.	Atom. steam pressure ------------------------	80 psi
6.	Specific steam volume @ 50 psi -------------	6.652 cu.ft/lb
7.	Estimated emulsion chamber pressure --------	50 psi.
8.	Lbs. atomizing steam/Hr. 4 x 400 (See Bulletin No. 5 - P.1)	1600 lbs.
8.1	Atomizing Steam/Lb. #6 Oil is: $\frac{4}{8.33 \times .98}$ =	.49 lb.
9.	Vol. atom. steam/sec.: $\frac{1600 \times 6.652}{3600}$ = ----------------------	2.96 cu.ft/sec
10.	Area of exit orifice sq. ft. = $\frac{.80}{144}$ ---------	.0055 sq.ft.
11.	Emulsion velocity = $\frac{.015 + 2.96}{.0055} = \frac{2.975}{.0055}$ ----	541 fps
12.	Ratio CWM/Emulsion = $\frac{.015}{2.975}$ = .005	
13.	Effective Erosion Index Velocity = .005 x 541= 2.71 fps	

.../2

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14. Est. ∠ impact in multi hole atomizer is 30°
and sin^{-1} 30° = 2

15. Total erosion velocity index -
steam atom., for multi hole
atomizer is 2.71 + 2 ------------------ 4.71 fps

16. If atom. fluid is compressed air at 80 psi and
50 psi in emulsion chamber we have

17. Vol. of air, SCFM, per US gal. oil
(see Bulletin 5, p. 1) 1.48 SCFM

17.1 Atomizing air/lb. #6 oil:
$\frac{1.48 \times 60 \times .076}{8.33 \times .98}$ = ---------- .827 lb.

18. Vol. of comp. air at 50 psi per sec., is:

$\frac{400 \times 1.48 \times 14.7}{60 \times 64.7}$ = 2.24 cfs

19. Total emulsion volume per sec. is
(.015 + 2.24) 2.26 cfs

20. Vel. with air atom. is: $\frac{2.26}{.0055}$ = ------------- 410 fps

21. Ratio CWM/Emulsion - $\frac{.015}{2.275}$ = .066

22. Erosion velocity index is (.066 x 410) ------ 217 fps

23. With impact of 30° total erosion index - air
atom., is: .2.7 + Sin^{-1}30° = 2.7 + 2 = -- 4.7 fps

Bulletin 56.43 - Tip Emulsion Atomizer

1. Exit port area per 1200 US gph -------------- 1 sq.in.

2. Max. Capacity ------------------------------- 400 US gph

3. Exit port area: $\frac{400 \times 1}{1200}$ = ---------------- 0.333 sq.in.

.../3

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4. Flow of CWM in cu. ft. per sec., is:

$$\frac{400 \times 8.33 \times 1.11}{62.4 \times 1.11 \times 3600} = \text{----------}\ 0.015\ \text{cfs}$$

5. Atom. steam pressure ------------------------ 80 psi

6. Estimated emulsion chamber pressure --------- 50 psi

7. Specific steam volume @ 50 psi -------------- 6.652

8. Lbs. atomizing steam/hr. (for 400 USgph)
(See bulletin 5643.1: p.1 and Fig.1 p.4) 495 lbs/Hr

8.1 Lbs. atom. steam/lb. #60, oil at 400USgph:

$$\frac{495}{400 \times 8.33 \times .98} = \quad .15\ \text{lb.}$$

9. Vol. of atom. steam per sec. is:

$$\frac{495 \times 6.652}{3600} = \text{----------------}\ 0.915\ \text{cfs}$$

10. Area of exit orifice, sq. ft., is: $\frac{0.333}{144}$ = -- 0.0023 sq.ft.

11. Emulsion Velocity = $\frac{.015 + 0.915}{.0023} = \frac{.93}{.0023}$ = 404 fps

12. Ratio CWM/Emulsion = $\frac{.015}{.93}$ = 0.016

13. Effective erosion velocity index =
0.016 x 404 = --------------- 6.464 fps

14. Add impact effect $\sin^{-1}30° = 2$
Total erosion index velocity = ----------- 8.464 fps
400 USgph
fuel rate

Bulletin 56.22/23

1. External steam atomization

2. Max. capacity ------------------------------ 250 US gph

3. Atom. Steam Press. ------------------------- 15-125 psi

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---

4. Fuel Pressure ------------------------------- 5-10 psi

5. Turn down ----------------------------------- 3.5-4:1

6. Dia. oil tube for 250 USgph ----------------- ½"

7. Area of oil tube (6) $\frac{.\ \frac{1}{4}^2}{144}$ = ---------- .00136 sq.ft.

8. Vol. flow of max. cap. per sec.

$$\frac{250 \times 8.33 \times 1.11}{62.4 \times 1.11 \times 3600} = \text{----------}\ .00935\ \text{cfs}$$

9. Velocity of fuel per sec. is: (Steam atom.)

$$\frac{.00935}{.00136} = \text{---------------------}\ 6.88\ \text{fps}$$

10. Single hole exit $\sin^{-1}180° = 0$

11. Atom. steam cons. (ref. Model 56.22 - Bulletin No. 7 is:

500 lbs/hr @ 85 psi for an oil
rate of 250 USgph

12. Atom. steam rate lb/lb#6 oil is:

$$\frac{500}{250 \times 8.33 \times .98} = \text{----------------}\ .24\ \text{lbs/lb. h6}$$

13. Atom. air rate @ 250 USgph oil rate is 1/3 steam rate expressed in SCFM

$$= \frac{500 \times 60 \times .076}{3 \times 250 \times 8.33 \times .98} = 0.37\ \text{lb}$$

.../5

Appendix 7

Fuel Velocities in AECO (Vortometric type) Atomizer

(Conamara Ltd.)

1.	Capacity basis - 20.10^6 Btu (#6 oil) =	134 USgph 0.31 lb/sec.
2.	Flow in cu. ft./sec.: $\frac{134 \times 8.33 \times 1.11}{62.4 \times 1.11 \times 3600}$ = ----------------------------	0.005 cfs
3.	Exit oil port area: 8 nozzles ea. .04" dia. $\frac{8 \times (\pi \times .02^2}{144}$ = ------------------------------------	7.10^{-5} sq.ft.
4.	Fuel only velocity, cfs: $\frac{.005}{7.10^{-5}}$ = ------------------------	71 fps
4.1	Estimated angle of impact --------------------------------	30°
5.	Wt. atom. steam per sec. - $\frac{.21 \times 134 \times 8.33}{3600}$ = ---------------	0.065 lbs at. steam/sec
6.	Atom. Steam Press.	85 psig.
7.	Estimated press. in Divergent Nozzle (k = 1.31 $\frac{14.7}{.5425}$ + 20% (est.) = 27 x 1.2 = --------------------- =	32.5 psia 17.8 psig
8.	Spec. Vol.saturated steam @ 32.5 psia. =------------------------	12.7 cu.ft/lb
9.	Atom. steam flow for 134 USgph = 12.72 x 0.065 = --	0.83 cfs atom.steam flow
10.	Estimated mean dia. of div. nozzle for cap. of 134 USgph.-------	0.75"

11.	Area at mean dia., sq. ft: $\dfrac{\pi \times \left(\frac{.75}{2}\right)^2}{144} =$	.0031 sq. ft.
12.	Vol. Emulsion flow/sec. 0.83 + 0.005 =	0.835 cfs
13.	Mean. Velocity through divergent nozzle: $\dfrac{.835}{.0031} =$	269 fps
14.	Ratio fuel/Emulsion: $\dfrac{.005}{.835} = .006$	
14.1	Abrasion Vel. Index No.: .006 x 269 =	1.6
15.	Angle of impact -----45°	
15.1	Abrasion factor: $\sin^{-1} 45^{\circ}$	1.41
16.	Total Abrasion index number	3.01
17.	Abrasion index fuel flow only through fuel orifices (item 4) $71 + \sin^{-1} 30^{\circ} = 71 + 2 =$	73 fps

APPENDIX NO. 8
SUMMARY

Summary of Atom. Cost Data
OIL

1.	Cost per lb. atom. air	\$0.002
2.	Cost per lb. atom. steam	\$0.0065
2.1	Cost ratio - equal specific consumption values: $\frac{.0065}{.002}$	= 3.25
3.	Cost per 100 USgph burning rate at load factor of .53 or 4643 hours/year is:	
3.1	Air @ .20 lb. specific rate Steam @ .25 lb. specific rate CWW	\$1483.00 \$6159.00
4.	Cost per 10^6 BTU/hr fuel input	
4.1	Fuel is a CWM with C.V. assumed	10,000 B.T.U./lb.
4.2	Air cons. is $\frac{10^6}{10000} \times .20$	20 lbs
4.3	Steam cons. is $\frac{10^6}{10000} \times .25$	25 lbs
	Then	
4.4	Cost of air/10^6 B.T.U./hr is: 20 x\$.002	= \$.04/hr.
4.5	Cost of steam/10^6 B.T.U. is: 25 x\$.0065	= \$.1625
5.	Cost ratio $\frac{\text{steam}}{\text{air}} = \frac{.1625}{.04}$	= 4.06

Appendix No. 8

Cost per Lb. of Air and Steam Atomizing Fluids

ITEM NO.	DATA AND CONDITIONS		VALUES
	ATOMIZING AIR COST PER LB.		
1.	Power cost assumed per Kw. Hr.		\$0.05
2.	Load factor assumed -53%		4643 hrs/Yr
3.	Atom. air pressure assumed, psi		100
4.	Theoretical H.P. per 100 ACFM (Ref.: Kent Mechanical Engineers Hand Book, 1936. Pages 1-52) $H.P. = 1.511\ p_1 \left[\frac{P_2}{P_1}^{0.29} - 1 \right]$ Where P_1 = atmos. press., psia P_2 = compressed air press. of 100 psig. = 114.7 psia		
5.	Then H.P. per 100 ACFM compressed from atmospheric press. to 100 psig. $= 1.511 \times 14.7 \left[\frac{114.7}{14.7}^{0.29} - 1 \right]$		
	$= 22.212\ (1.8145 - 1)$	=	18.1 H.P.
	i.e. theoretical power requirement	=	13.5 Kw
6.	Mechanical efficiency of compressor assumed to be 80%, then actual Kw of power per 100 ACFM is: $\frac{13.5}{.8}$	=	17 Kw
7.	Atom. rate of 100 ACFM = 6000 cfh requiring		17 Kw
8.	Specific vol. of air at 14.7 psia is 13.16 cu. ft. at 70° F./lb. air.		
9.	Then energy required per lb. atomizing air/hr at 100 psig is $\frac{13.16}{6000} \times 17$	=	0.037 Kw/Hr
10.	Hence cost per lb. of atom. air per hour = .037 x \$0.05	=	\$0.002/Hr.
		=	.2¢/Hr.

ITEM NO.	DATA AND CONDITIONS	VALUES
	ATOMIZING STEAM COST PER LB.	
11.	Cost per U.S. gal #6 oil @ 150,000 B.T.U./U.S. gal. is	= $0.775
12.	Heat to generate 1 lb. steam at 100 psig from feedwater temp. (assumed) of 221°F is: Steam Enthalphy: 1189 BTU Heat in Feedwater: (221-32) 189 BTU Heat input/lb. steam 1000 BTU	
13.	Cost of oil per lb. steam per hour at 80% efficiency is: $\frac{1000}{150,000} \times \frac{0.775}{.80}$	= $0.0065 = .65¢/lb

ITEM NO.	DATA AND CONDITIONS	VALUES
	ECONOMIC COMPARISONS	
14.	Cost Ratio $\frac{\text{Steam}}{\text{Air}} = \frac{.65}{.20}$ =	3.25
15.	Case History - Ref. Table B - 500 USgph burner rate	
15.1	Sect. 2 Spec. Atom. air rate:	.20 lb. air
15.2	Sect. 3 - do - steam rate:	.25 lb. steam
15.3	Burning rate/burner	500 USgph
15.4	Load Factor 53%	
15.5	Hours per year 8700 x .53	4643 hours
16	Atom. air cost/burner/year 500 x 8.33 x 0.98 x 4643 x 0.20 x $0.002	7580.00
17.	Atom steam cost/burner/year 500 x 8.33 x 0.98 x 4643 x .25 x $0.0065	30,796.00
18.	Cost ratio allowing for spec. cons. rate is: $\frac{\text{steam}}{\text{air}} = \frac{30796}{7417}$ =	4.06

APPENDIX No. 9
COM - CWM - Conversions
Comparative Fuel (only) Costs

Source: EPRI Reports RP-1455- 1&2 RP 1895-4 1)

Item	Price	Information Source 1)	Equivalent Coal Comparisons F.O.B. Eastern Seabord
1) CWM at Eastern Seabord 4% ash	$3.50/1.10^6$ BTU from . prod. plant of rated capacity up to 1.10^6 tons/yr	EPRI-RP 1895-4 Rolfe Manfred cost CWM per ton See item 3	
2) #6 fuel oil Eastern Seabord	See item 6 page 2		
3) One ton CWM 1.1% S, 70% coal @13000 BTU/lb = $18.2.10^6$ BTU/ton CWM	(Item 1 x item 3) = 18.2 x 3.5 = $63.70	EPRI-1895-4	CWM per ton $63.70
4) One ton 1.1% S Bituminous coal at Eastern Seabord CWM plant C.V. value of 13,000 BTU/lb	Mine mouth $30/ton =$1.15/10^6$ BTU Trans. $18/ton Del. cost Eastern Seabord = $48/ton	EPRI-RP 1455-1	Bituminous @13000 BTU/lb = $48.00/ton
5) Cost CWM equiv. to one ton 13000 BTU/lb Bituminous coal	$\frac{26.10^6}{18.2.10^6}$ x$63.70 = $91.00 + 2.6% H_2O loss 2.37 Total equiv. cost CWM/ton coal = $93.37	EPRI-RP 1455-1	CWM equivalent BTU/ton Bituminous is 1.46 tons CWM @ a cost of $93.00

---

1) Tech. Article: Coal-Water Slurry as an Alternate Fuel
By Rolfe Manfred - Coal Technology '82, Houston Texas, Dec 9, 1982

APPENDIX No. 9
COM - CWM - Conversions
Comparative Fuel (only) Costs

Source: EPRI Reports RP-1455- 1&2 RP 1895-4

Item	Price	Information Source	Equivalent CoAL Comparisons F.O.B. Eastern Seabord
5.1) Conversion Capital Costs See item 7 p. 3			
6) a) Cost low S #6 oil (1%-1.5% S) with C.V. of 150,000 BTU/USgal Sp. G. of .97 giving 184,000 (approx.) BTU/1b	4.50/10^6 BTU $= \frac{150,000}{10^6} \times 4.50 =$ \$0.675 per USgal plus est. 5% heating cost \$0.040 Total cost/gal. \$0.715	EPRI RP1455-1	F.O.B. Eastern Seabord \$0.715/USgal
b) Cost #6 oil/bbl.	42 x \$0.715 = \$30.00		\$30.00/bbl
c) Cost of #6 oil of equivalent heat to 1 ton 1.1% S CWM having C.V. of $18.2.10^6$ BTU/ton	$\frac{18.2.10^6}{42 \times 150,000} \times$ \$30.00=		\$87.00
d) % saving using CWM versus #6 oil (Fuel BTU basis only)	$\frac{87.00 - 63.70}{87.00} =$		26.8%

APPENDIX No. 9
COM - CWM - Conversions
Comparative Fuel (only) Costs

Source: EPRI Reports RP-1455- 1&2 RP 1895-4 1)

Item	Price	Information Source 1)	Equivalent Coal Comparisons F.O.B. Eastern Seabord
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5) Cost CWM equiv. to one ton 13000 BTU/lb Bituminous coal	$\frac{26.10^6}{18.2.10^6}$ x$63.70 = $91.00 + 2.6% H_2O loss 2.37 Total equiv. cost CWM/ton coal = $93.37	EPRI-RP 1455-1	CWM equivalent BTU/ton Bituminous is 1.46 tons CWM @ a cost of $93.00

1) Tech. Article: Coal-Water Slurry as an Alternate Fuel
By Rolfe Manfred - Coal Technology '82, Houston Texas, Dec 9, 1982

APPENDIX No. 9
COM - CWM - Conversions
Comparative Fuel (only) Costs

Source: EPRI Reports RP-1455- 1&2 RP 1895-4

Item	Price	Information Source	Equivalent CoAL Comparisons F.O.B. Eastern Seabord
5.1) Conversion Capital Costs See item 7 p. 3			
6)			
a) Cost low S #6 oil (1%-1.5% S) with C.V. of 150,000 BTU/USgal Sp. G. of .97 giving 184,000 (approx.) BTU/lb	$4.50/10^6$ BTU $= \frac{150{,}000}{10^6} \times 4.50 =$ \$0.675 per USgal plus est. 5% heating cost \$0.040 Total cost/gal. \$0.715	EPRI RP1455-1	F.O.B. Eastern Seabord \$0.715/USgal
b) Cost #6 oil/bbl.	42 x \$0.715 = \$30.00		\$30.00/bbl
c) Cost of #6 oil of equivalent heat to 1 ton 1.1% S CWM having C.V. of $18.2.10^6$ BTU/ton	$\frac{18.2.10^6}{42 \times 150{,}000} \times \$30.00 =$		\$87.00
d) % saving using CWM versus #6 oil (Fuel BTU basis only)	$\frac{87.00 - 63.70}{87.00} =$		26.8%

APPENDIX No. 9
COM - CWM - Conversions
Comparative Fuel (only) Costs

Source: EPRI Reports RP-1455- 1&2 RP 1895-4

	Item	Price	Information Source
	600 Mw Plant		
7)	Total plant Invest. incl precip. at $13.2.10^6$ dollars	assumed basis CWM = COM capital cost	R.P. 1455-1 Tables 2.4 p.2.35
	Total plant invest.	$\$42.17.10^6$	
7.1)	Preproduction, inventory credit, & Capacity Charge 1)	$\$35.61.10^6$	
	TOTAL CAPITAL REQUIREMENT	$77.78.10^6$	
8)	Annual oil cons. for a 600 Mege plant at .54 L.F. @ 10000 BTU heat rate	$\frac{600 \times 1000 \times 10{,}000 \times 8760 \times .54}{150{,}000}$	$= 189.10^6$ USgals
9)		Cost: $189.10^6 \times .\$.715$ Savings per item 6(d)	$= \$135{,}000.00$ $\times .268$ $= 36.18.10^6$/yr

1) This sum includes economic cost of de-rating boiler

APPENDIX No. 9
COM - CWM - Conversions
Comparative Fuel (only) Costs

Source: EPRI Reports RP-1455- 1&2 RP 1895-4

Item	Price	Information Source	
10) Gross (simplified) yeild on total capital requirement	Capital cost, depreciation, etc. not included.	$\frac{36.10^6}{77.8.10^6}$	= 46%
11) Gross payback time		1/.46	= 2.174 years
		Important for net ROI based on complete accounting record.	See EPRI RP 1455-1 Table 2.4 p. 2.35

Appendix No. 10

Fuel Velocities and Shear Rate of Exit Orifices of C.E. Canada Burner Designed for Chatham

ITEM NO.	Description	
1.	Burner developed for Chatham 22.5 MWe demonstration plant is a modified Y jet provided with centre-fire air (combustion air surrounding atomizer tip) plus a divertor refractory shroud. See Fig. 26	
2.	Atom. steam fluid: lb./lbCWM	0.12 lb
3.	Max. CWM flow/burner	0.0231 cfs
3.1	Weight CWM/sec @ spec. G of 1.11=.0231 x 62.4 x 1.11=	1.6 lbs
4.	Number of orifices	7
5.	Total area of orifices, sq.in. (given by C.E.)	0.207 sq.in. = 0.00144 sq.ft.
5.1	Velocity of fuel only, fps is .0231/.00144	= 16 fps
6.	Dia. of orifices sq. in.: $= 2x \sqrt{\frac{.207}{7 \times \pi}}$	0.194 M. = 0.00135 ft.
7.	Weight of atom. steam/sec: $= \underline{.12 \times 1.60}$	= 0.192 lb.
8.	Spec. vol. of steam at assumed press. of 50 psi in exit orifices is	6.62 cu.ft./lb.
9.	Total vol. of emulsion flow through exit ports per sec. is: (6.62 + x 0.192) + 0.0231 = 1.27 + 0.023	6.6431 = 1.234 cfs
10.	Velocity of emulsion flow, fps is: $\frac{1.2944}{0.00144}$	= 898 fps

Appendix No. 10

ITEM NO.	Description	
11.	Ratio fuel/emulsion vol. is: $\frac{0.231}{1.294} = .01785$	
12.	"Effective" velocity is $.01785 \times 898$	= 16 fps
13.	Angle of impact of fuel & atom. steam assumed 30° $+ \sin^{-1} 30° = 2$	
14.	Hence erosion index is (16+2)	= 18 fps
15.	Shear rate of emulsion is: $\frac{898}{7 \times \frac{.00135}{2}}$	= 190,053 ft.sec.^{-1}
16.	Shear rate of fuel only is: $\frac{16}{7 \times \frac{.00135}{2}}$	= 3395 ft.sec.^{-1}

ARCO Petroleum Products Company
Harvey Technical Center
[illegible] East Sibley Boulevard
Harvey, Illinois 60425

Venture Planning and
Business Development

APPENDIX II
Coal & Rheological Data
Arco Petroleum Products Co.

December 1, 1982

Mr. Ralph Grossman
650 North Atlantic Avenue
Unit 106
Beachwinds Condominium
Cocoa Beach, FL 32931

Dear Mr. Grossman:

During your recent visit to the Harvey Technical Center to discuss various aspects of coal R&D programs, I agreed to provide you with typical ultimate and proximate analysis on coals from Atlantic Richfield's holdings as well as general rheological information developed during the course of our work with coal slurries. This information is summarized in the following attachments.

Attachment I shows typical proximate and ultimate analysis on samples of our western bituminous and subbituminous coals, respectively. I believe these data are self explanatory.

Attachment II is a series of figures, preceeded by a brief explanation for each figure, that provides a broad overview of methods for measuring the rheological characteristics of slurries, the type of data developed using each of the methods described and some of the limitations of each methodology.

Attachment III is an illustration proceeded by a brief explanation of the impact certain parameters, i.e., coal type, coal loading, choice and concentration of additive, etc., have on the rheological characteristics of coal water mixtures. As noted, some of the variables shown have a rather dramatic impact.

I believe this information will satisfy your questions. Good luck in your project.

Very truly yours,

Frank J. Chloupek

F. J. Chloupek
Manager
Venture Planning and Business Development

jpk:jah
ATTACHMENT

ATTACHMENT I

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601 · AREA CODE 312 726-8434

PLEASE ADDRESS ALL CORRESPONDENCE TO.
16130 VAN DRUNEN RD., P.O. BOX 127
SOUTH HOLLAND, IL 60473
OFFICE TEL. (312) 264-1173

ARCO PETROLEUM PRODUCTS CO.
Harvey Technical Center
400 East Sibley Blvd.
Harvey, IL 60426

March 19, 1982

Kind of sample reported to us	Coal
Sample taken at	Arco Petroleum Products Co.
Sample taken by	Arco Petroleum Products Co.
Date sampled	9/17/82
Date received	3/11/82

Sample identification by Arco Petroleum Products Co.

Black Thunder
Western Sub-Bituminous

I.D. No. and Expense Coding:
8136-8956-A2139

Analysis report no. 71-93110

PROXIMATE ANALYSIS	% Weight As received	% Weight Dry basis
Moisture	31.67	XXXXX
Ash	4.55	6.66
Volatile	31.24	45.72
Fixed Carbon	32.54	47.62
	100.00	100.00
Btu/lb.	8249	12072
Sulfur	0.40	0.58
Alk. as Na_2O	----	0.15
SULFUR FORMS		
Pyritic Sulfur	0.10	0.15
Sulfate Sulfur	0.01	0.01
Organic Sulfur	0.29	0.42
WATER SOLUBLE ALKALIES		
Na_2O	XXXX	XXXX
K_2O	XXXX	XXXX

FUSION TEMPERATURE OF ASH	Reducing	Oxidizing
Initial Deformation	2060 °F	2110 °F
Softening (H=W)	2230 °F	2280 °F
Softening (H=½W)	2270 °F	2320 °F
Fluid	2350 °F	2400 °F

H is Cone Height
W is Cone Width

% EQUILIBRIUM MOISTURE	XXXX
HARDGROVE GRINDABILITY INDEX	54 @ 22.2% Moisture
FREE SWELLING INDEX	
Silica Value	43.32
Base: Acid Ratio	0.88
T_{250} Temperature	2220°F

Cu in ash = 230 ppm

ULTIMATE ANALYSIS	% Weight As received	% Weight Dry basis
Moisture	31.67	XXXXX
Carbon	47.66	69.75
Hydrogen	3.28	4.80
Nitrogen	0.87	1.27
Chlorine	0.03	0.04
Sulfur	0.40	0.58
Ash	4.55	6.66
Oxygen (diff)	11.54	16.90
	100.00	100.00

MINERAL ANALYSIS OF ASH	% Weight Ignited Basis
Silica, SiO_2	27.14
Alumina, Al_2O_3	14.59
Titania, TiO_2	1.16
Ferric oxide, Fe_2O_3	6.80
Lime, CaO	24.07
Magnesia, MgO	4.63
Potassium oxide, K_2O	0.26
Sodium oxide, Na_2O	2.14
Sulfur trioxide, SO_3	17.82
Phos. pentoxide, P_2O_5	0.70
Strontium Oxide, SrO	0.29
Barium Oxide, BaO	0.38
Manganese Oxide, Mn_3O_4	0.02
Undetermined	0.00
	100.00

Fouling Index	1.88
Slagging Index	0.51

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

R A Houser

R. A. HOUSER, Manager, Midwest Division

Charter Member

Original Copy Watermarked For Your Protection

Subject Mt. Gunnison Coal (F-Seam)
Sheet number of
Title Western Bituminous
By K. C. CHUANG
Date

Representative Sample 9/10

		R. O. M.	
		As Received	Dry
Proximate Analysis	Moisture	7.00	—
	Ash	8.67	9.32
	Volatile	36.01	38.72
	Fixed Carbon	48.32	51.96
Ultimate Analysis	Carbon	67.85	72.96
	Hydrogen	4.67	5.02
	Nitrogen	1.21	1.30
	Chlorine	0.02	0.02
	Oxygen	10.02	10.78
Sulfur Form	Pyritic Sulfur	0.06	0.06
	Sulfate Sulfur	0.02	0.02
	Organic Sulfur	0.48	0.52
	Total Sulfur	0.56	0.60
Heating Value BTU/lb.		11,920	12,817

Subject Mt. Gunnison Coal (T-Seam)
Sheet number of
File Western Bituminous
By K. C. CHUANG
Date

Representative Sample, 9/10

		As Received
Analysis of Ash, % Weight	SiO_2	59.95
	Al_2O_3	22.14
	TiO_2	1.06
	Fe_2O_3	8.72
	CaO	2.34
	MgO	1.18
	K_2O	2.07
	Na_2O	0.62
	SO_3	1.45
	P_2O_5	0.18
	Undetermined	0.29
Base/Acid		0.18
Fouling Index		0.11
Slagging Index		0.11
Silica Ratio		83.04

Subject Mt. Gunnison Coal (F-Seam)

Sheet number 218

File

By K. C. CHUANG

Date

LL.. Sample 9/10

Fusion Temperature and Viscosity of Ash

	As Received	
	Reducing	Oxidizing
Initial Deformation Temp. °F	2340	2670
Softening Temp. (H=W), °F	2680	2700+
Softening Temp. (H=½W), °F	2700+	2700+
Fluid Temp., °F	2700+	2700+
Silica Ratio	83.04	
Viscosity at 2600°F, Poises *	>1000	

* From Reid-Cohen Correlations for Calculation of Ash Viscosity

ATTACHMENT II

Notes for Figure Series A

A.1 Types of shear stress/shear rates responses found in slurry rheology.

A.2 Mathematical equations of the models shown in previous graph.

A.3 Example showing the change in rheological properties of a thixotropic fluid as the rheological measurement proceeds. Fluid reaches an "equilibrium" value of the rheological properties after a long period of shear (i.e. stirring).

A.4 The physical basis of the Brookfield viscometer. The Brookfield is one of three types of viscometers used in measuring slurry rheology.

A.5 The physical basis of the FANN or HAAKE viscometers.

A.6 The physical basis of an extrusion tube rheometer.

A.7 Range of application of two types of viscometers.

A.8 Typical effect of solids loading on viscosity of a coal-oil slurry. Similar effect is observed in coal-water slurries at lower viscosity.

A.9 Addition of an agent to eliminate particle settling is required in some systems. Effect of the stabilizer is demonstrated in this figure.

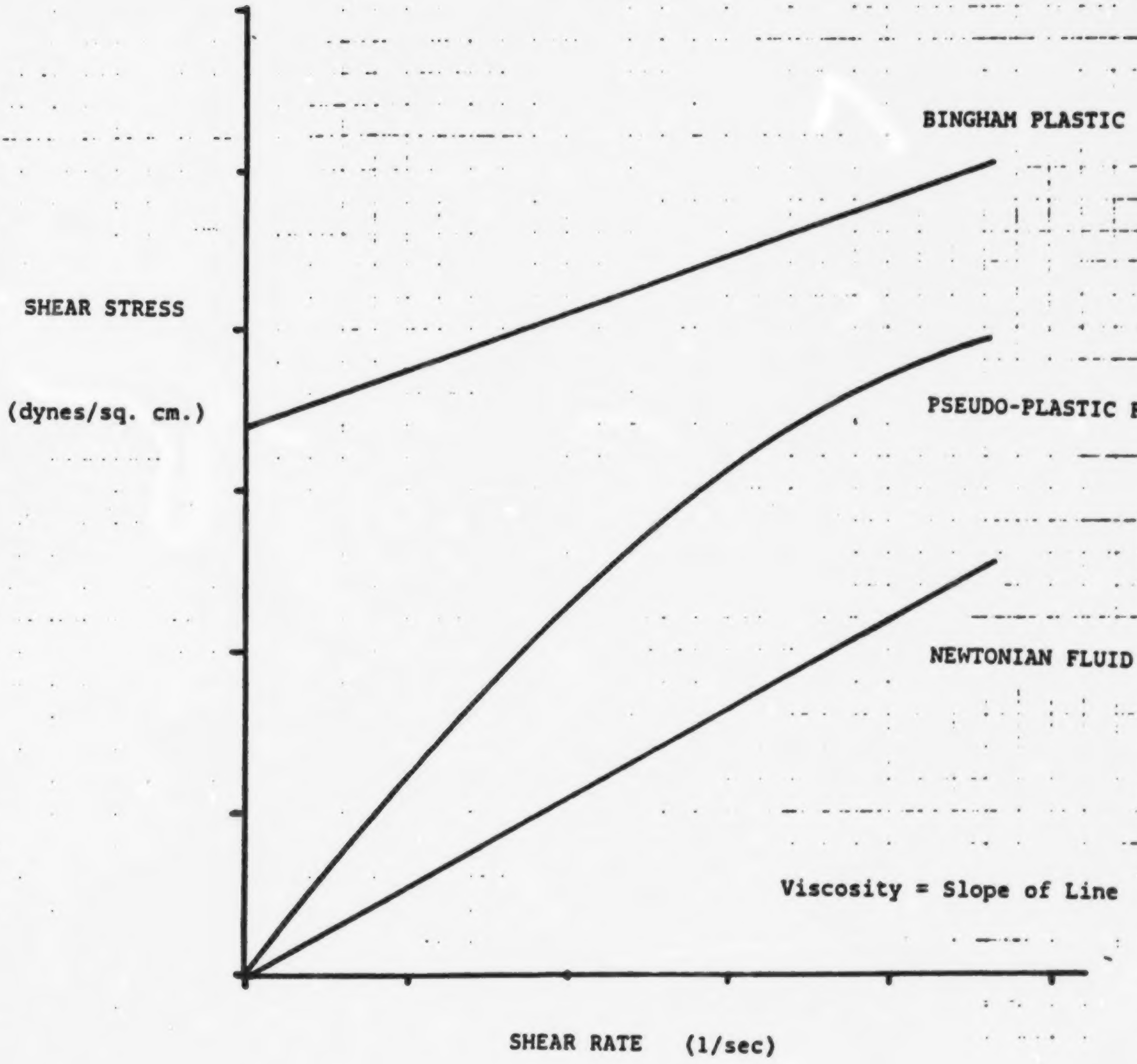
A.10 A highly automated HAAKE viscometer can measure the thixotrophy of a slurry. The manually operated FANN will miss the detail but will give the "equilibrium" value fo the rheological properties.

A.11 A small gap between the rotor and bob of a concentric cylinder viscometer (FANN and HAAKE) cannot be used when the particles in the slurry become too large. The particles will bridge the gap and cause incorrect readings.

$$\frac{\text{Instrument Gap Size}}{\text{Particle Size}} > 10$$

A.1

MODELS USED IN SLURRY RHEOLOGY



A.2

Rheological Model Equations

Newtonian Model

Shear Stress = Viscosity x Shear Rate

Bingham Plastic Model

Shear Stress - Yield Strength = Bingham Viscosity x Shear Rate

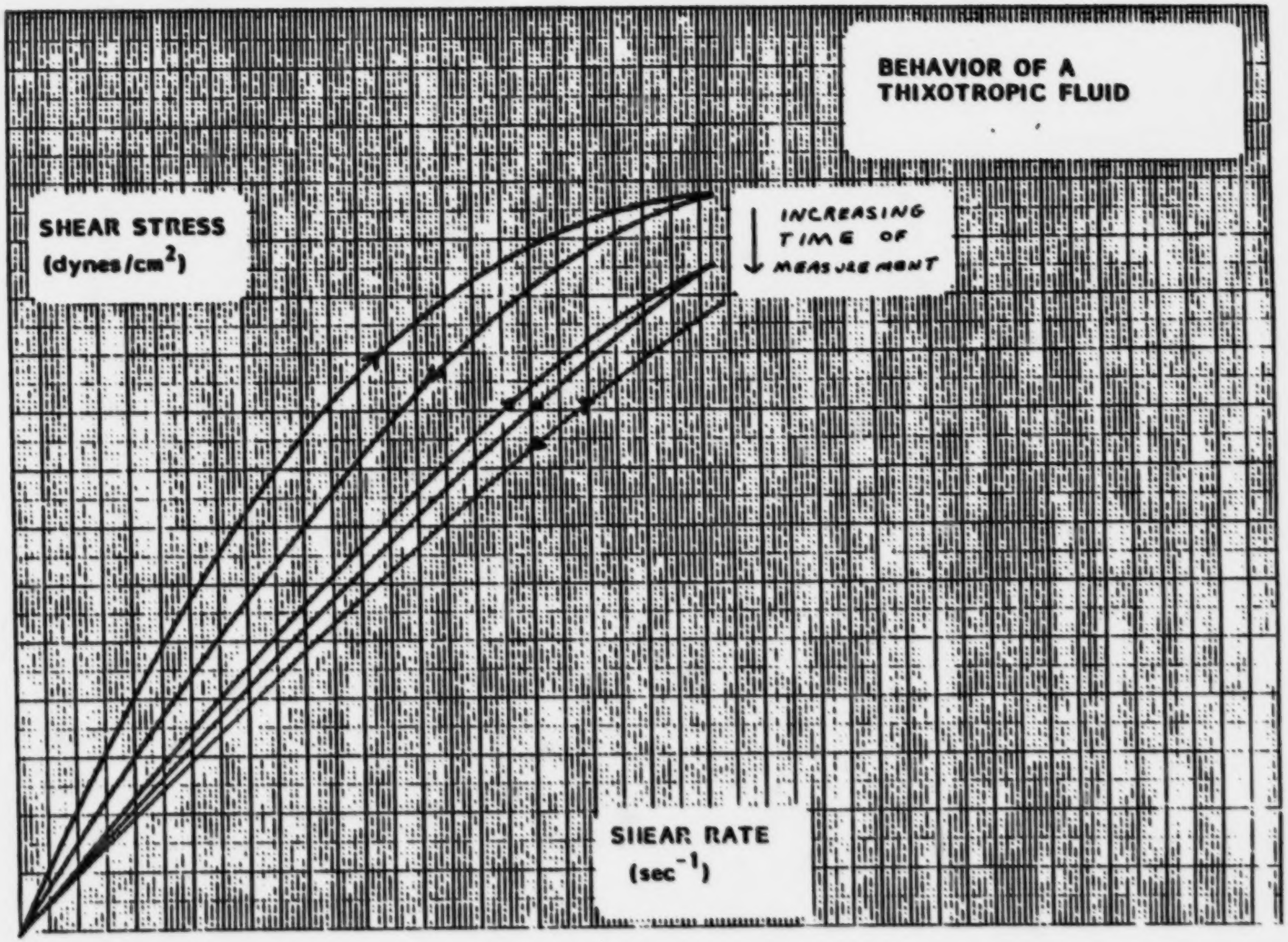
Pseudo-Plastic Model

Shear Stress = Consistancy x $(\text{Shear Rate})^n$

Where n is the flow behavior index

Definition of Viscosity

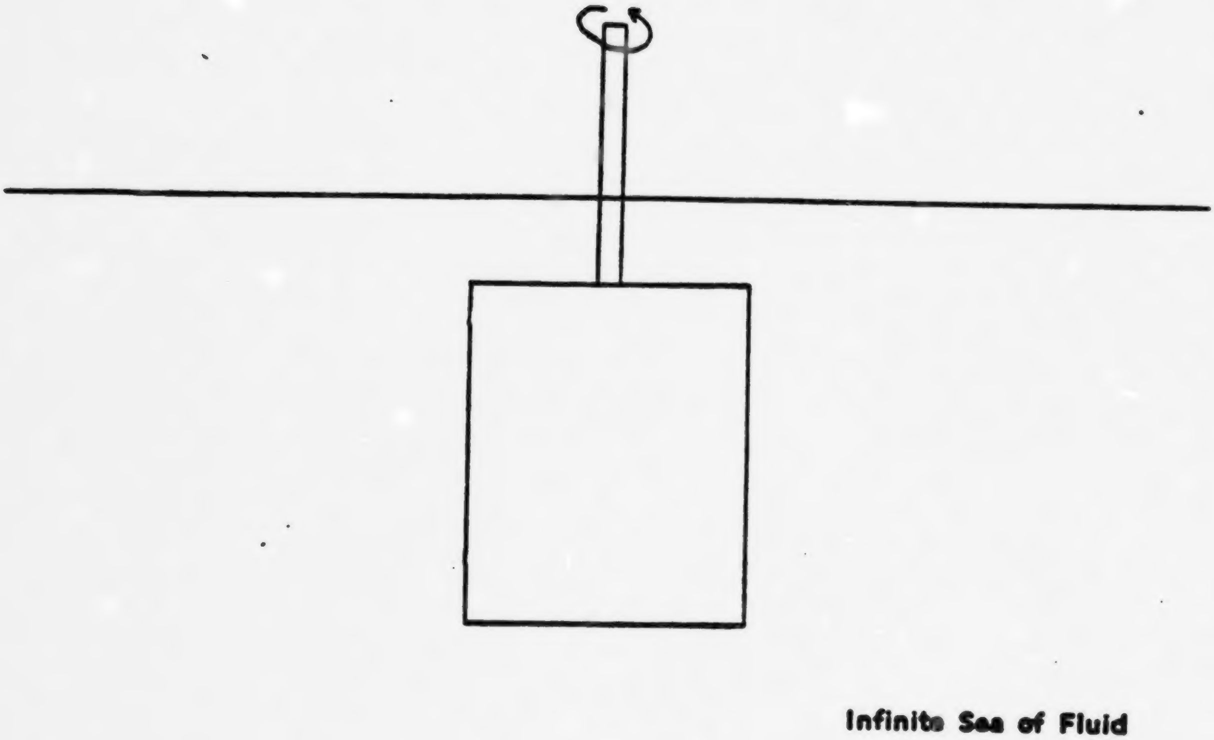
$$\text{Viscosity} = \frac{\text{Shear Stress}}{\text{Shear Rate}}$$



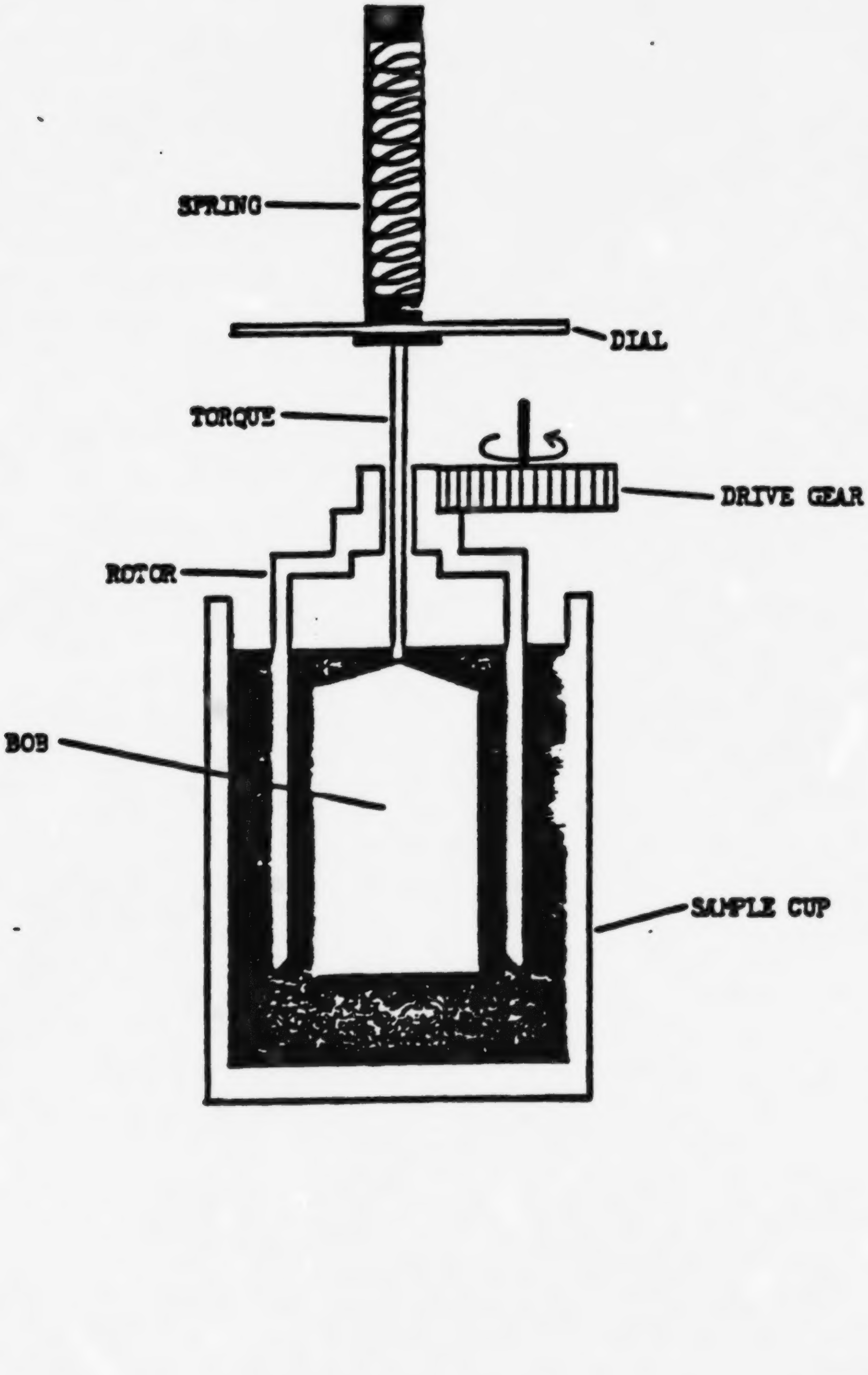
BEHAVIOR OF A THIXOTROPIC FLUID

A.4

BROOKFIELD VISCOMETER

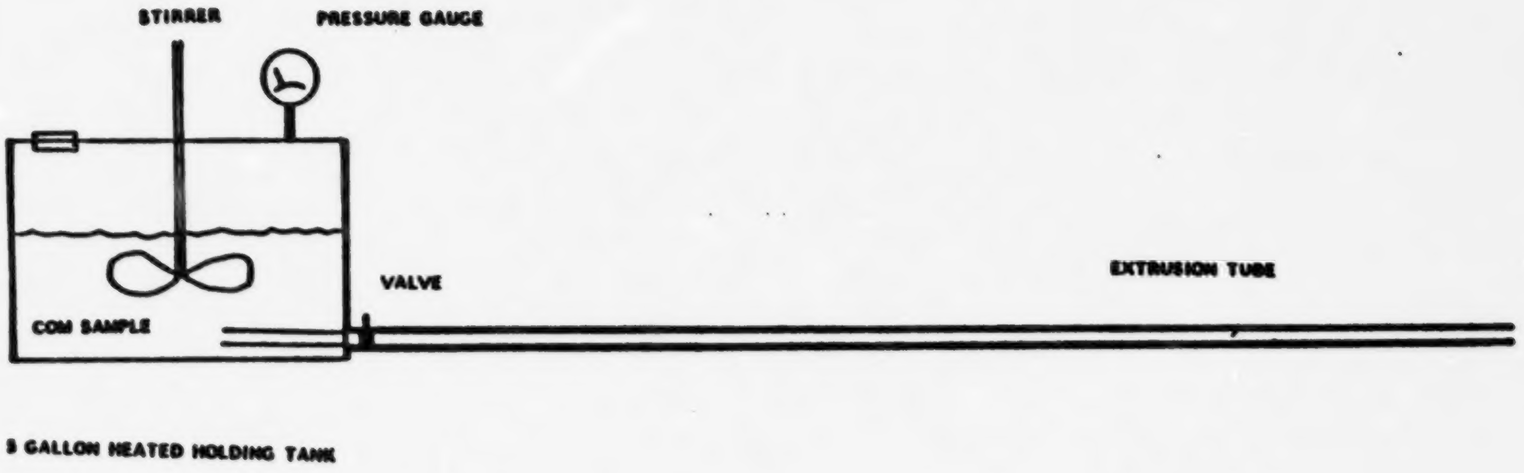

Infinite Sea of Fluid

HAAKE/FANN Viscometer

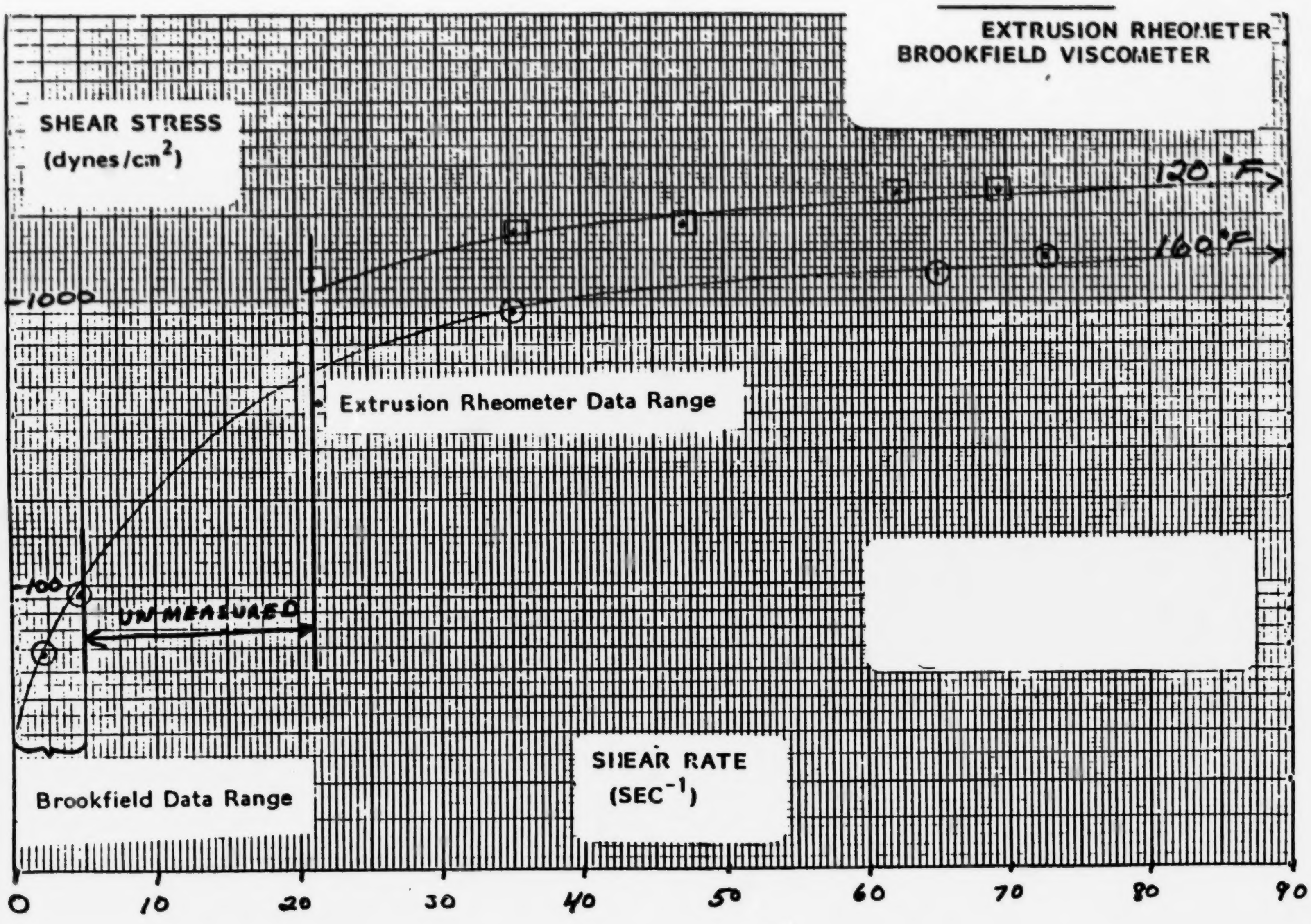

SPRING
DIAL
TORQUE
DRIVE GEAR
ROTOR
BOB
SAMPLE CUP

A.6

EXTRUSION TUBE RHEOMETER

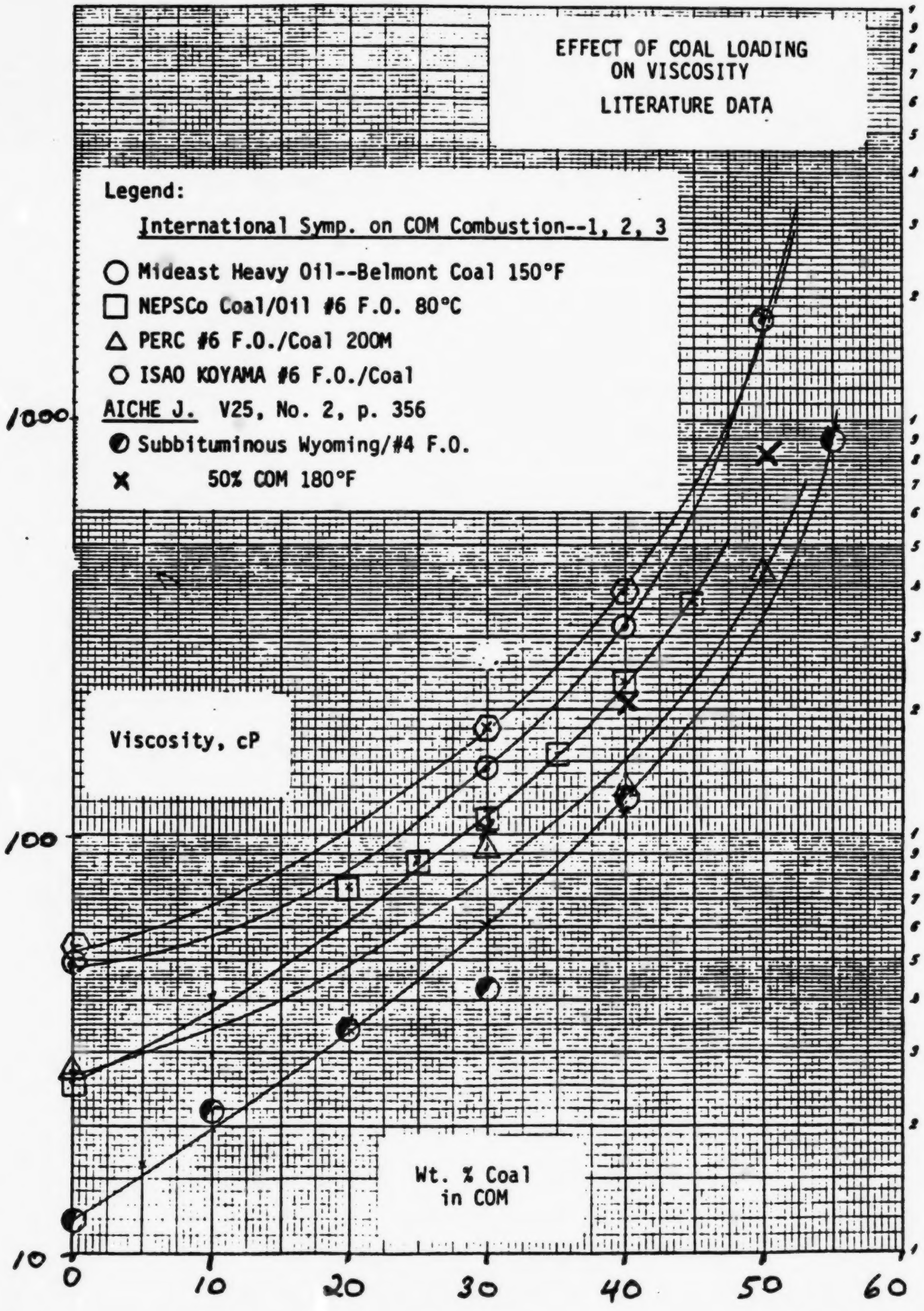

STIRRER
PRESSURE GAUGE
VALVE
EXTRUSION TUBE
COM SAMPLE
5 GALLON HEATED HOLDING TANK

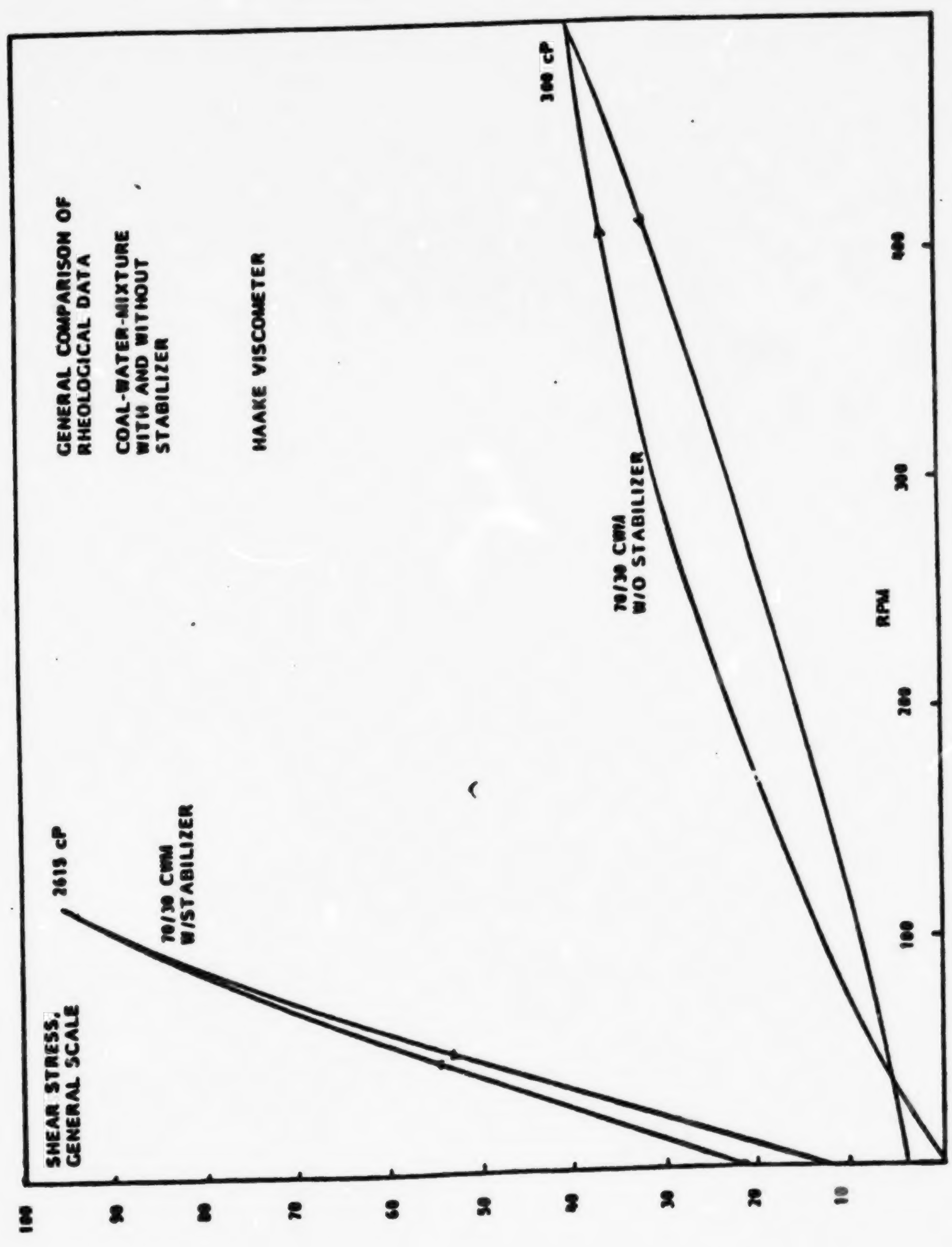
VISCOMETER WORKING RANGE



A.7

A.8


EFFECT OF COAL LOADING ON VISCOSITY
LITERATURE DATA
Legend:
International Symp. on COM Combustion--1, 2, 3
○ Mideast Heavy Oil--Belmont Coal 150°F
☐ NEPSCo Coal/Oil #6 F.O. 80°C
△ PERC #6 F.O./Coal 200M
○ ISAO KOYAMA #6 F.O./Coal
AICHE J. V25, No. 2, p. 356
● Subbituminous Wyoming/#4 F.O.
× 50% COM 180°F
Viscosity, cP
Wt. % Coal in COM
1000
100
10
0
10
20
30
40
50
60


GENERAL COMPARISON OF RHEOLOGICAL DATA
COAL-WATER-MIXTURE WITH AND WITHOUT STABILIZER
HAAKE VISCOMETER
SHEAR STRESS, GENERAL SCALE
2615 cP
70/30 CWM W/STABILIZER
70/30 CWM W/O STABILIZER
300 cP
RPM
100
200
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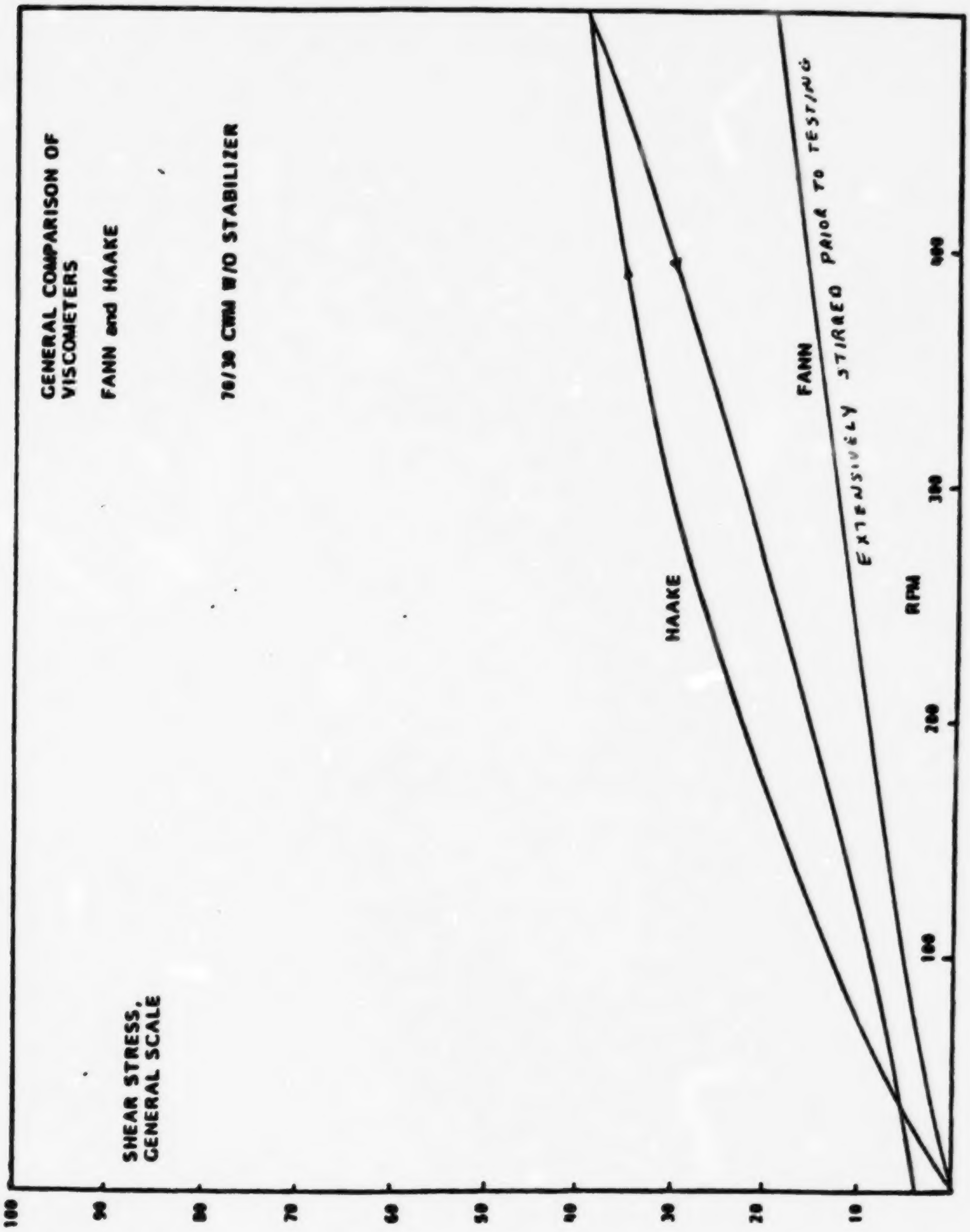
GENERAL COMPARISON OF VISCOMETERS
FANN and HAAKE
70/30 CWM W/O STABILIZER
SHEAR STRESS, GENERAL SCALE
HAAKE
FANN
EXTENSIVELY STIRRED PRIOR TO TESTING
RPM
100
200
300
400
10
20
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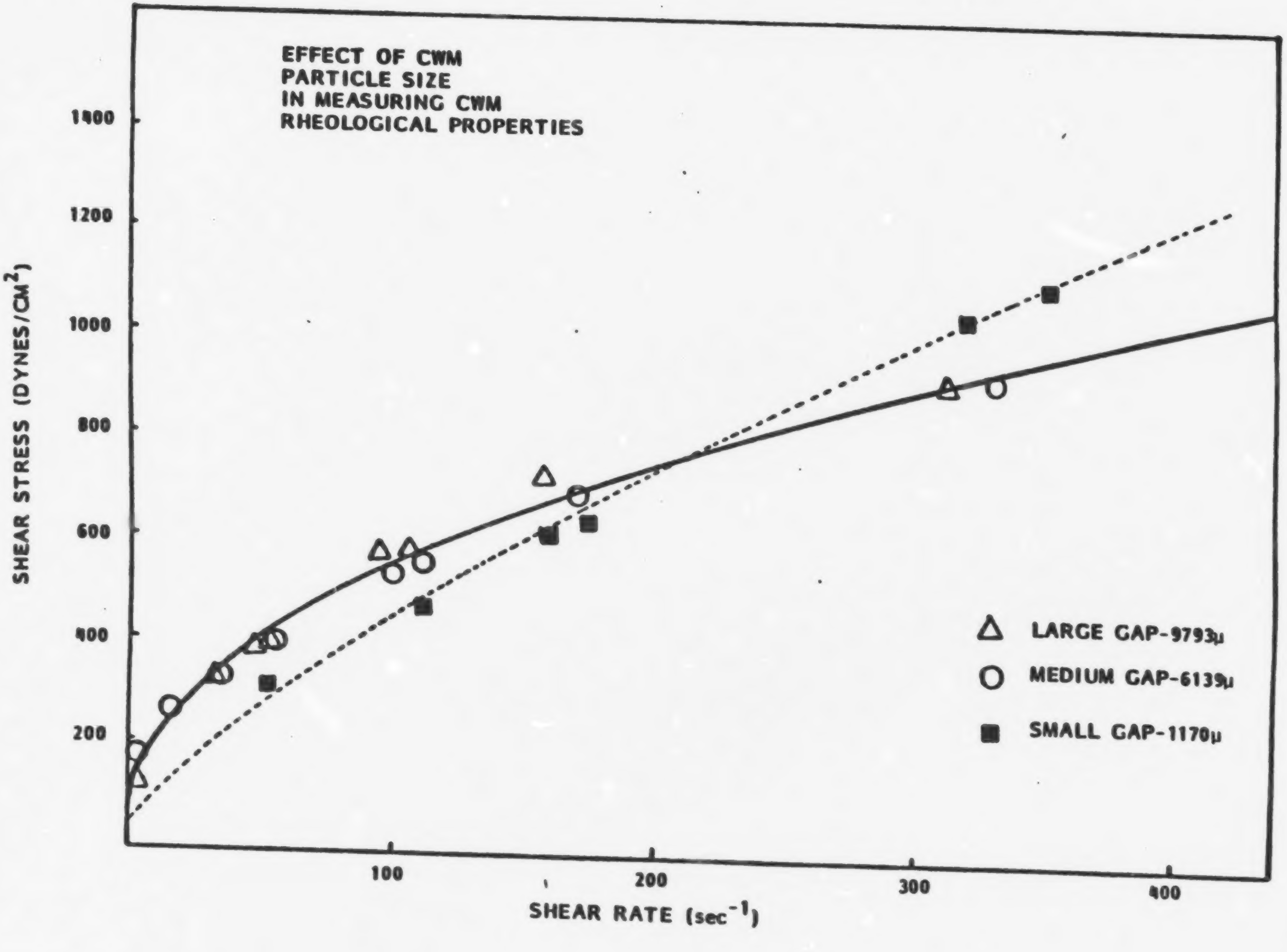
90
100



EFFECT OF CWM
PARTICLE SIZE
IN MEASURING CWM
RHEOLOGICAL PROPERTIES

ATTACHMENT III

NOTES TO FIGURE B-1

1. The loadings shown are on a dry coal basis. Note that the viscosity of the sub-bituminous coal mixtures is higher relative to coal loading. This is due to water adsorption.

2. Additive A is superior to additive N for viscosity reduction.

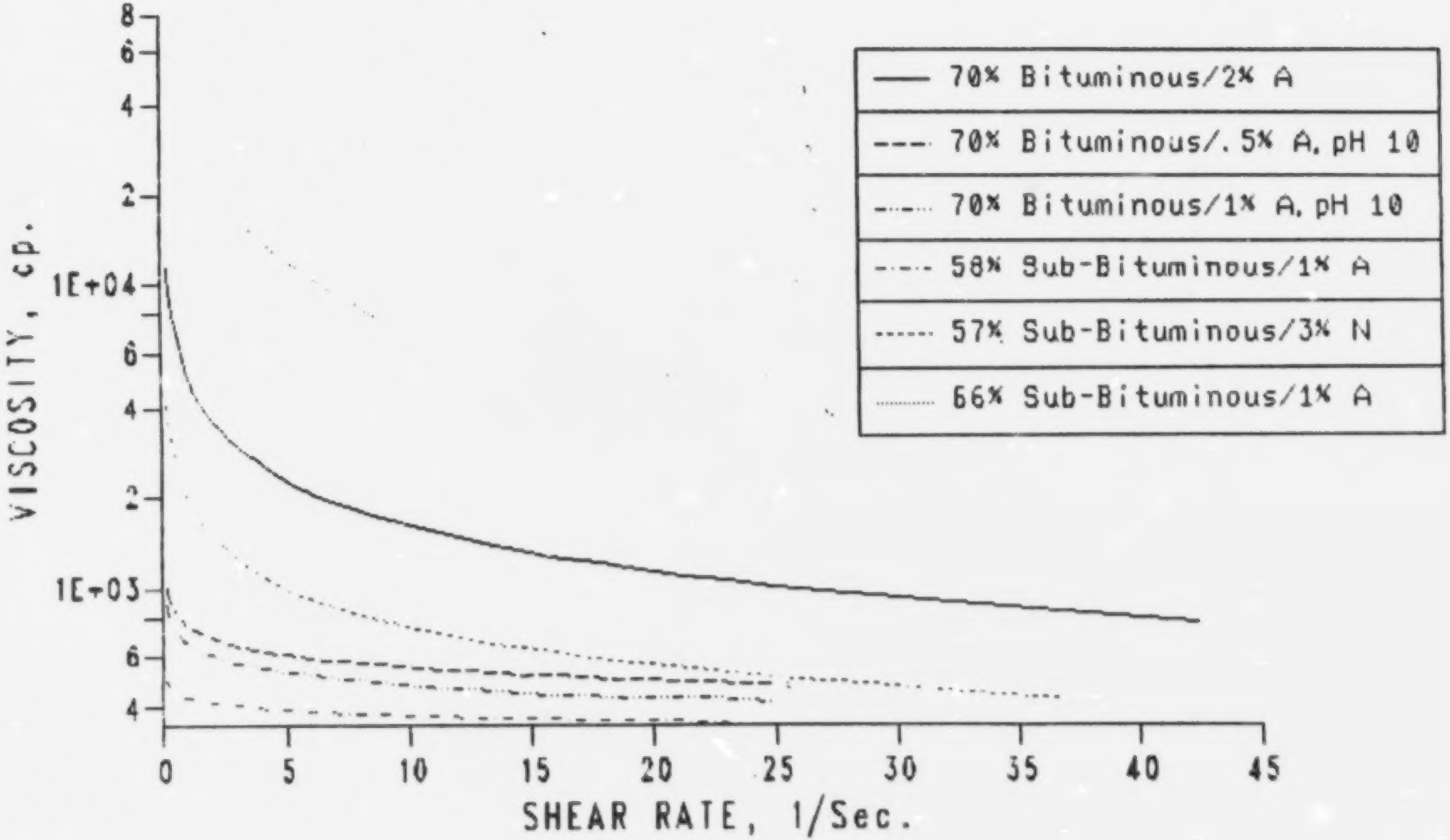
3. The pH of all mixtures is about 8, except for those marked. Viscosity decreases with increasing additive concentration and at higher pH.

4. All mixtures are thixotropic, i.e., viscosity decreases with increasing shear rate.

5. None of these mixtures contain a stabilizing additive.

FIG. B-1

VISCOSITY OF COAL-WATER MIXTURES
(Brookfield Viscosimeter Data)



Technical Paper

TECHNICAL PAPER
NO. 1

Commercialization of coal-water slurries

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Barberton, Ohio

Presented to
9th Energy Technology Conference
Washington, D.C.
February 16, 1982

BR-1210

Babcock & Wilcox
a McDermott company

Commercialization of coal-water slurries

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PGTP 82-11

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B&W considers coal-water mixtures (CWMs) to be the most advantageous alternative to oil and gas fuels because the need for on-site coal handling and preparation equipment is excluded and because the use of oil is completely eliminated. In addition, if a low-ash coal is used in the mixture or if the coal is beneficiated, derating of the units will be minimized. Recent work has enabled a number of organizations to prepare pumpable mixtures (slurries) containing approximately 70 percent pulverized coal and 30 percent water. These slurries are stablilized to retard the settling of coal particles and rheological properties are tailored to insure good flow properties by careful variation of grinding processes and additives. Limited scale combustion tests have been performed to date and the most critical question of whether direct-fired un-dewatered slurry can achieve stable combustion without requiring support fuel has been answered positively.[1]

Once it had been determined that direct firing was feasible, a CWM commercialization program was initiated and is presently underway.

Coal-water mixture commercialization program

The elements we perceived as critical to achieve commercial applications are:

- Availability of the CWM
- Development of a combustion system for the direct firing of high-density CWMs
- Availability of a host site to demonstrate the fuel effects (such as stability, erosion, slagging, and fouling)

Availability of fuel

Several CWM suppliers currently are capable of providing the fuel. We have investigated the rheological and combustion properties of mixtures produced by Slurrytech and by Atlantic Research, Inc. under joint B&W/Slurrytech; B&W/EPRI funding. Additional slurries will be investigated under a current EPRI/B&W program. The manufacturers claim that they can produce the fuel on a continuous basis, that it can meet a top size, viscosity, Btu and percent specification, and that it can be produced in quantities great enough to fuel a 25 MW industrial or utility demonstration during 1982. Some of the potential suppliers plan to have larger production demonstration plants on stream with the capacity to support a 100 MW utility demonstration in 1983. We have experience with slurries produced from four different parent coals, and therefore, have confidence that the fuel will be available as stated when a host site is located.

Combustion system

A burner/atomizer optimization program is currently in progress at B&W's Alliance Research Center. The objectives of the B&W burner program is to increase the data base and quantify the variables in fuel supply/burner design effects upon combustion efficiency and turndown. The gathered information supports the commercial application evaluation concerning the suitability of CWM as a reliable and acceptable alternative fuel supply.

Coal-water mixtures are characterized by the properties routinely measured for liquid and solid fuels. Standard ASTM methods for analysis of coal and coke are employed. B&W methods provide additional information. The following information is considered minimal and required for each run: Moisture content, proximate analysis, ultimate analysis, heating (calorific) value, elemental ash analysis, ash fusion temperatures, density, particle size distribution, Brookfield viscosity, and a settling test (short-term). Fly ash from the combustion tests are collected and analyzed for carbon content (by ultimate analysis) for comparison to the base fuels fired in the same facility.

The Alliance Research Center has several test furnaces which range in scale from 30,000 Btu/hr (8.8 kW) input to 50 million Btu/hr (14.7 MW) input. To minimize costs by minimizing fuel requirements, a relatively small furnace (4 million Btu/hr, or 1.2 MW, pulverized coal) and an existing oil burner (8 million Btu/hr, or 2.4 MW) were used for the initial test burns. The present test series utilizes the same furnace, but the burner has been designed specifically for flexibility with liquid fuels. The furnace, or basic combustion test unit (BCTU), has been utilized for many years as the first step in our in-house burner development programs. Supportive to all combustion tasks is the analysis of the pumping characteristics and characterization of the fuel properties.

One objective of the present burner development work is to produce a hardware configuration for CWM combustion that will provide stable ignition, reasonable turndown, and efficient carbon utilization. The base or starting point for the burner design configuration has been a circular-type designed specifically for R&D programs. This burner design (Figure 1) permits air flows and swirls to be varied over the input range to determine optimum conditions. It is comprised of four annular zones. The flow to each zone can be metered and controlled independently of the other zones. Swirl (ratio of combustion air tangential momentum to axial momentum) can be varied without varying air flows. The outermost zone of the burner containing the air

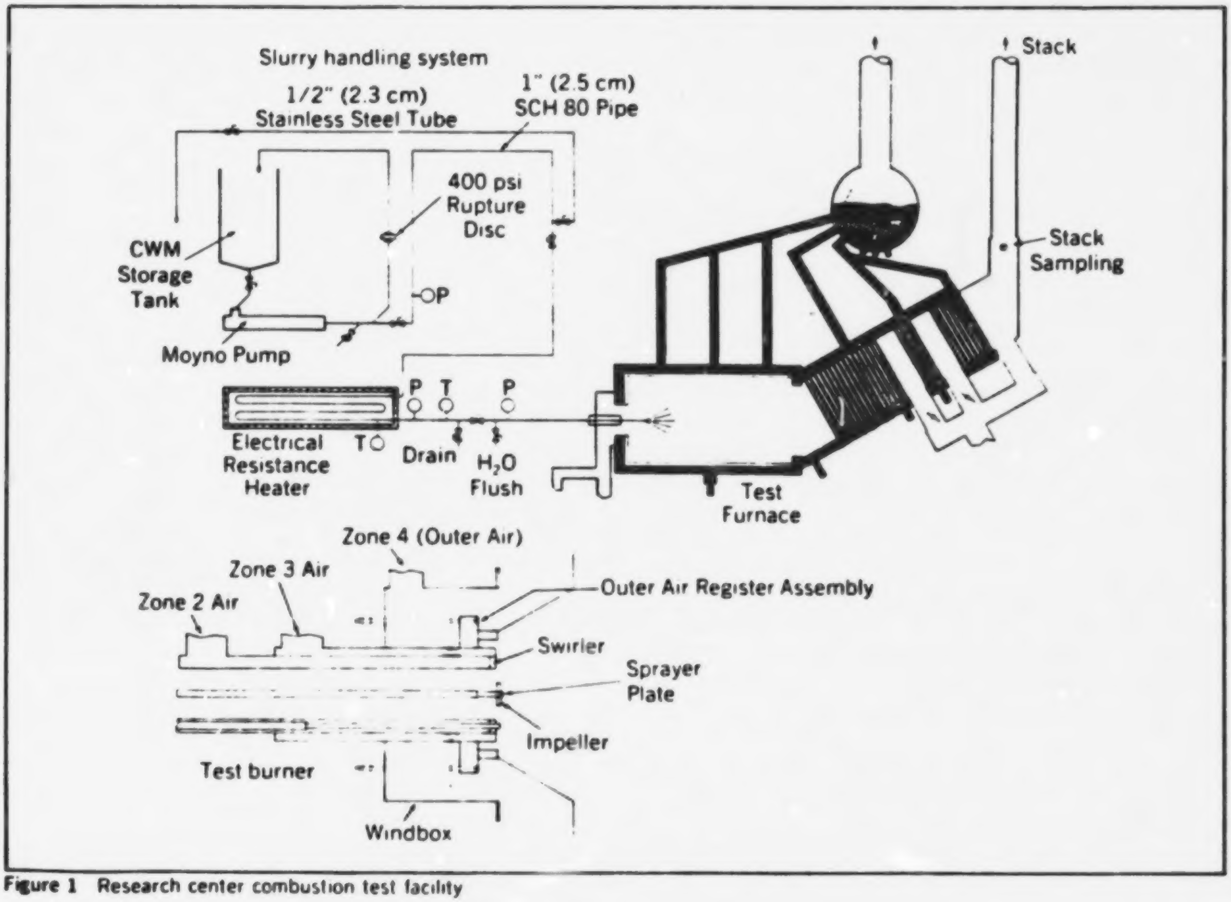
Slurry handling system
1/2" (2.3 cm) Stainless Steel Tube
1" (2.5 cm) SCH 80 Pipe
400 psi Rupture Disc
CWM Storage Tank
OP
Moyno Pump
Stack
Stack Sampling
P
T
P
Electrical Resistance Heater
TO
Drain
H_2O Flush
Test Furnace
Zone 4 (Outer Air)
Zone 3 Air
Zone 2 Air
Outer Air Register Assembly
Swirler
Sprayer Plate
Impeller
Test burner
Windbox

Figure 1 Research center combustion test facility

registers is Zone 4. The outer diameter of this zone is equal to the throat diameter. However, in this zone, a sleeve can be inserted to reduce the effective diameter of the throat by a factor of 2. The sleeve permits a wide variation in velocities without requiring a burner change. The spin vanes in Zone 3 permit extensive swirl variability that has proved valuable in previous developmental work.

Atomizer design

During the initial CWM combustion testing performed at B&W, the sprayer plate utilized was the one that resulted in the best combustion without plugging. This sprayer plate was modeled after one developed by B&W for firing MgO pulp liquors and injecting lime/water slurries (30 percent solids) into dry SO_2 scrubbers. It is a dual-fluid atomizer using air as the atomizing fluid.

The present testing has utilized each of our Y, T and racer atomizer designs. A modified T-Jet atomizer using air and internal premix has been determined as the most promising by the present combustion tests.

Results obtained to date (December 15, 1981) with the T-Jet atomizer/flexible burner design are most encouraging. Turndowns of 4:1, maximum secondary air temperatures of 600 F and minimum of 300 F, atomizing air consumption less than 1/10 lb per pound of coal water slurry, and CO emissions always below 100 ppm have all been attained. The atomizer/burner optimization program also has demonstrated cold furnace light-off capability and identified erosion-prone areas in the atomizer. The atomizer zones vulnerable to erosion can be protected with inserts and subjected to tests during the next wear test series. Our next steps are to further investigate sensitivity to atomizing medium quantities and to apply the optimized atomizer to a standard burner design. The flexible test burner will be removed and the original standard circular type reinstalled for the next series of tests.

Currently under construction at the Alliance Research Center is an atomization facility. This facility will have the capability of quantitatively and qualitatively characterizing the atomization obtained with a variety of test fluids under specific test conditions with the use of laser diagnostic techniques. The characterization desired will include particle velocity and particle size distribution. An estimate of particle number density will be obtained using particle sizing interferometry. The optimized T-Jet atomizer design will be tested on this facility as soon as it is operational.

Atomizer material selection

The initial tests utilized carbon-steel modified Y-Jet atomizers which lasted for 4 hours of firing. Future series will use the T-Jet optimized atomizer fitted with composite inserts. The insert approach is one B&W has successfully utilized commercially on MgO and limestone slurries. Nine different insert materials are currently under test and range from tungsten carbide to silicon nitride including ceramics. The current test series utilizing the T-Jet indicated significant wear life increase (+ 600 percent) over the initial series.

Fuel Characteristics

Characterization of the fuels during the initial series was necessary to permit comparisons between the parent coal and its associated coal-water slurry. Our initial test series reviewed the characteristics extensively on the first two parent coals — Upper Freeport and Pittsburgh No. 8. The present series is utilizing Ohio No. 6 coal for the CWM, and the characterization results obtained indicate that similar relationships exist between the parent coal and its associated coal-water slurry.

Fuel Analysis

The Upper Freeport coal seam ranges in volatile content from 15 to 43 percent on a dry basis; the Upper Freeport coal used to produce the CWM had an as-received volatile content of 17.2 percent. The Pittsburgh seam No. 8 coal had an as-received volatile content of 38 percent. These two parent coals provided the widest volatile extremes that could be expected in normal utility coals and they produced CWM as-fired volatile contents of 13.1 and 29.4 percent, respectively.

Fuel Ash Analysis

Ash chemistry is a major factor that affects steam generator design criteria such as furnace sizing, the clear side spacing required for convection pass heat transfer surfaces, and the number and location of sootblowers. Indices of the base-to-acid ratio in the ash, coupled with the amounts of sodium and sulfur, have been used (as indicators of fouling and slagging potential, respectively), to classify bituminous coals for slagging and fouling potentials for many years. The classification establishes base design requirements. If the ash chemistry is changed (e.g., the sodium or sulfur increases), additional conservatism must be designed into the steam generator to permit maximum continuous rating

Table 1
Fuel analyses

	Upper Freeport		Pittsburgh	
	CWM "as fired"	parent coal "as received"	CWM "as fired"	Pittsburgh "as received"
Total moisture, %	24.8	2.6	29.1	3.4
Solids content, %	75.2		70.9	
Proximate analysis, %				
Moisture	24.8	2.6	29.1	3.4
Volatile matter	13.1	17.2	29.4	39.1
Fixed carbon	48.7	62.5	34.6	48.9
Ash	13.4	17.7	6.9	8.6
Ultimate analysis, %				
Moisture	24.8	2.6	29.1	3.9
Carbon	54.2	69.6	52.5	71.7
Hydrogen	3.0	3.9	3.6	5.1
Nitrogen	0.83	1.14	0.86	1.38
Sulfur	1.93	2.3	1.6	2.2
Ash	13.4	17.7	6.9	8.6
Oxygen (diff.)	1.84	2.76	5.44	7.62
Density, g/cc	1.32			
Gross Heating Value				
Btu per lb	9470	12,100	9440	12,940
Btu per lb (M&A free)	—	—	—	—
Ash analysis (spectrographic %)				
Silicon as SiO_2	57.2	50.00	48.87	42.77
Aluminum as Al_2O_3	20.0	24.75	22.33	30.37
Iron as Fe_2O_3	13.0	16.73	16.88	17.50
Titanum as TiO_2	1.9	1.45	1.24	1.10
Calcium as CaO	2.0	1.70	1.49	1.95
Magnesium as MgO	0.3	0.57	0.65	0.60
Sodium as Na_2O	1.29	0.26	2.64	0.46
Potassium as K_2O	2.17	2.11	2.34	1.74
Sulfur as SO_3	1.7	1.77	2.84	1.87

Ash fusion temperatures, °F

	Coal-UF		CWM-UF		
Atmosphere	Red.	Oxid.	Red.	Oxid.	Red.
A (I.D.)	2360	2580	2390	2520	—
B (S.T., sp)	2450	2660	2480	2640	—
C (S.T., HSp)	2500	2680	2530	2660	—
D (F.T., 1/16")	2640	2720	2640	2720	—
E (F.T., flat)	2740	2750+	2750	2750	—

(MCR) operation with a higher slagging or fouling classification.

Comparing elemental ash analysis of the CWM to that of the parent coals (Table 1) showed that the production of CWM resulted in increased sodium content. However, the magnitude of the increase was not sufficient to change the CWM fouling index from that generated for the parent coal. Also, because the sulfur content was not increased, our slagging classification would not change from that indicated by the parent fuel. CWMs can, therefore, be evaluated on the ash characteristics of the parent coal. Each CWM alternative fuel would have to be evaluated with respect to the compatability of its fuel ash properties, with the design of the particular steam generator being considered for fuel conversion.

Pumping and Handling

Prior to the initial series of tests, a CWM pumping and handling facility was constructed. The initial data obtained from that facility indicates that the CWMs meeting specifications exhibited pipeline pressure drops similar to those of heated coal-oil mixtures and were higher than straight No. 6 oil. Data was collected across test pipe sections of ½ in., 1 in., and 1½ in. diameter pipe. Flow rates up to approximately 5 gpm were attained. The data demonstrated that the slurries tested were pseudoplastic (pseudoplasticity is the flow property of a liquid whereby its apparent viscosity decreases with increasing shear rate). Measurements have shown that the CWM samples tested exhibited the property of thixotropy indicated by a decrease in apparent viscosity in time as the slurry was sheared at a constant rate.

The facility currently is being expanded to include 3- and 4-in. pipe loops and a larger capacity progressive cavity pump to examine flow properties and erosion characteristics at higher velocities. These investigations will utilize many different CWMs with varied solid concentrations.

Burning Profiles

B&W uses burning profiles to determine stability potential and residence times required for a test fuel as compared to the thousands of known fuels. In this test, a fuel sample is heated in a flowing stream of air and its rate of weight change is continuously measured. As a result of oxidation and combustion, volatile combustion products are formed and the fuel sample loses weight. The burning profile plots the rate of sample weight loss as a function of increasing furnace temperature. The generated profile identifies that fuel's combustion characteristics.

Profiles for the Pittsburgh No. 8 and Upper Freeport CWM are shown in Figure 2. The first peak indicates loss of moisture and the second broad peak represents oxidation. The areas under the curve are proportional to moisture content and heat content for the respective peaks.

CWM performance duplicated the experience with the base fuels. Our burning profiles indicated that stability was expected to be a problem with the low-volatile Upper Freeport coal, and the residence time required for Pittsburgh No. 8 to obtain maximum carbon utilization was expected to be less than that required for the Upper Freeport coal. Experimental results confirmed the burning profile analysis.

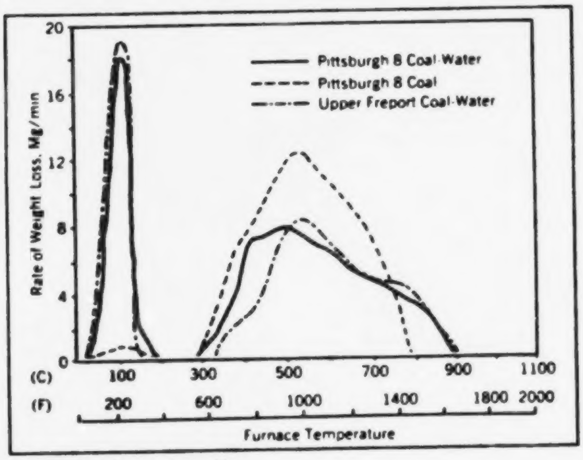

Figure 2 Burning profiles

Settling Rate

The CWMs provided to B&W were not specifically stabilized by the manufacturers for long shelf life, but because it was desirable to determine settling rate, a sample of the Upper Freeport CWM was allowed to stand undisturbed for a one-week period. At the end of that period, material was extracted from the top, middle, and bottom of the container. Solids contents were 71.6, 74.4, and 78 percent, respectively, which indicated that some settling occurred during the period. The observed settling rates were extremely long compared to those observed for coal-oil mixtures.

Demonstration

The availability of a suitable host site to permit a firing demonstration is a necessary link in the commercialization chain. Selecting the best site of the many offered by both utility and industrial clients has involved studies to establish judgment criteria. Our studies have reviewed conversion capabilities for oil designs and coal designs presently firing oil. The options studied included possible conversion to a matrix of alternative fuels, including conventional pulverized coal, coal-oil mixtures, coal-water mixtures and even replacement of the steam generator in total with a 100 percent MCR conventionally fired pulverized-coal steam generator. The scope of the studies has been limited to B&W's normal scope of supply, and therefore, the costs presented here for conversions/modifications do not include such items as coal storage silos, coal inventory, coal storage real estate, coal handling and coal unloading equipment. The studies have indicated that each candidate and its associated coal is unique and must be studied individually.

Coal-oil and coal-water mixtures

The approach taken in both the liquid coal base fuels is to maintain full unit capability by retaining the existing oil firing system. By retaining the oil firing capability at all times, the risk of conversion to coal mixtures is not significant as the unit would be available for extended periods of time. A new piping system would be supplied for the coal- mixture fuel based on information gained in the ongoing laboratory development work.

The studies attempted to answer these questions:

1. What capacity is available when firing a CWM?
2. What are the costs associated when converting to a CWM?

The major load-limiting factors are furnace design (slagging), furnace outlet temperatures (fouling), superheater and reheater metal temperatures, attemperation spray quantities, and gas side erosion. The environmental restrictions (e.g., particulate, SO_2, NO_x, and ash) apply equally to all the coal base options. We have performed and are performing engineering studies on units ranging in size from 15 MW to 400 MW, including both coal-capable and oil-capable designs. For this paper, the study unit selected is a B&W steam generator rated at 1,450,000 lb/steam/hr (220 MW) designed for oil firing only (Figure 3). It is 36 ft wide, 28 ft deep, firing horizontally opposed with 8 burners arranged four-high on the front wall and four-high, two-wide on the rear wall. The steam generator type is referred to as "El Paso" and is typical of B&W's standard designs offered for oil/gas firing. The maximum continuous load was specified as 5 percent overpressure, overflow, and low feedwater temperature condition. These conditions result in a steam flow of 1,535,000 lb/hr at 1005 F/1005 F and 2150 psig generating 243 MW. All percent-MCR references are to this overload condition.

This is a specific unit, and therefore, contains something unique (in this case, a negative draft conversion). It is presented simply, however, to demonstrate our iteration process. The objectives of our study were to determine (for items within our normal scope):

1. Conversion cost to direct pulverized coal and resultant new MCR with no modifications to pressure parts.
2. Conversion costs to coal-oil mixtures.
3. Conversion costs to CWMs.
4. Modifications to increase MCR for each of the fuel options and associated estimated costs.

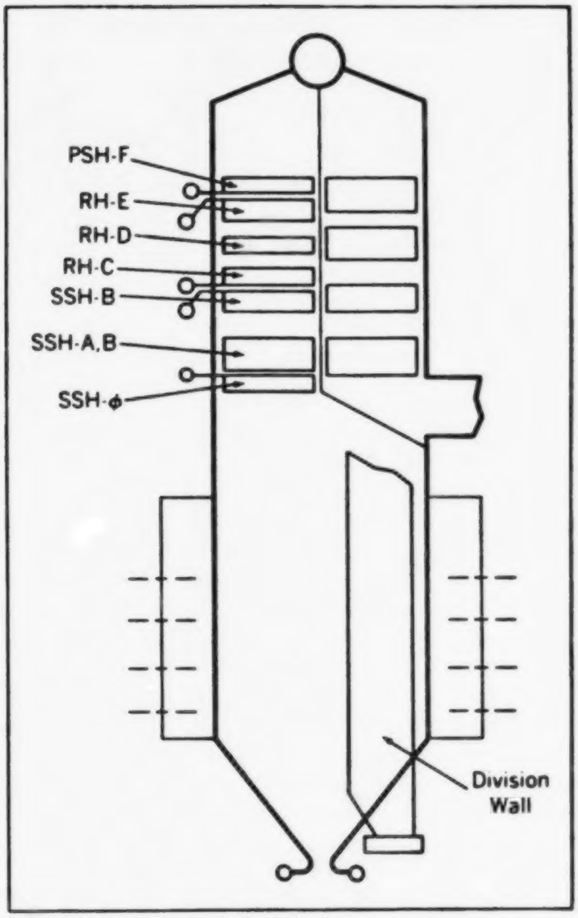

Figure 3 Side sectional of study unit

Evaluation

The three alternative fuels have been reviewed in each of the following areas:

Furnace Design: Proper furnace design is paramount for reliable boiler operation and performance. The furnace must be designed large enough to complete combustion in coal-fired boilers, to be able to sufficiently cool the flue gas before it enters the convection pass, and to minimize slagging on furnace wall tubes and the surfaces located in the upper furnace. The furnace should further be designed to provide uniform flue gas flow with the flattest possible temperature profile at the furnace outlet to prevent slagging, fouling and metal temperature problems in the convection banks of the boiler.

Six important factors that affect slagging in the furnace are the following:

- The heat input per burner
- The clearance between burners, furnace walls and the lower hopper
- The heat input per ft^2 of furnace cross sectional areas — "plan area heat release rate"
- The burner zone heat release rate (HA/SC$_1$)
- Furnace volume heat release rate — furnace liberation
- Mass gas flow at the furnace arch

A comparison of the study unit design to our present design standards for the study coal (South African TCOA double-washed power station smalls) will be presented next. The fuel is rated as low-slagging and low-fouling. Abrasion qualities are high on sliding and low on impact.

Heat Input Per Burner: On new units designed for pulverized-coal firing, the maximum burner input is limited to about 220 MBtu/hr. The study unit burners have an input of about 130 MBtu/hr. Burner input is not expected to be a problem while firing coal, coal-oil or coal-water mixtures.

Burner Clearances: Experience on coal-fired boilers has indicated that there are minimum clearances between burners and water-cooled surfaces (i.e., vertical walls, hopper slopes, and furnace arches) necessary to avoid excessive slagging and excessive spot absorption rates.

The existing burners at 70 percent of the original design do meet our recommended minimum sidewall top burner to first convection pass surface and division wall clearances for coal, coal-oil and coal-water mixtures. The furnace height limit is slightly encroached upon (2 ft) for those fuels.

Plan Area Heat Release: A most important criteria for evaluating furnace slagging potential is the level of heat input per ft^2 of furnace plan area. The present Babcock & Wilcox limit for coal-fired boilers is in the range of 1.5 to 1.9 MBtu/ft^2-hr, and is dependent upon the slagging severity (classification) of the coal ash. Our design limits (established in the 1960s) previously were higher, in the range of 2.1 MBtu/ft^2-hr. It is not practical to build a larger furnace to be able to reduce this value, but division walls could be added to avoid massive derating of the unit capacity. This unit has a half division wall already installed. The actual furnace and actual fuel are the final judge in this heat release criteria and our predictions do have to be conservative. The plan area heat release rate is within our present standards and will not limit direct coal, coal-oil or coal-water fuels maximum continuous ratings for this base coal.

Burner Zone Heat Release: Present standards for coal-fired boiler burner zone heat release values are approximately 400 to 550 MBtu/ft^2-hr. This level is used both as a slagging indicator and as a NO_X generation correlator. This study unit existing burner matrix produces a heat release rate in the defined zone below 500 MBtu/ft^2-hr. This rate is within our present standards and will not limit direct coal, coal-oil or coal-water maximum continuous ratings for this base coal.

Furnace Liberation Rate: During the era of small pulverized-coal-fired steam generators (smaller than 100 MW) liberations up to 30,000 Btu/ft^3, hr were not uncommon. Increasing this rate to 40,000 Btu/ft^3, hr would increase the carbon loss slightly due to the shortened residence time. Decreasing this rate to 10,000 Btu/ft^3, hr would increase the carbon loss due to the cooler furnace holding properties such as volatile levels, ash content, and coal quality. The larger steam generators currently being specified (1980's mean size — 580 MW) coupled with EPA NO_X emission limitations have forced larger plan areas. The increased sophistication in predicting slagging/fouling behavior has placed limits on furnace exit gas temperatures which in turn has forced larger (longer) furnaces to control that exit temperature. The combination of these factors has driven present liberation rates downward to about the 13,000 Btu/ft^3, hr level. The potential increase in carbon loss has been offset by increased burner turbulence and by the increase in residence time. Furnace liberation rate, as an index of carbon loss, therefore has lost much of its importance as a design index. The study unit liberation rate on oil is about 27 MBtu/ft^3, hr and slightly higher on direct coal, coal-oil or coal-water fuels. The liberation rate will not limit maximum continuous ratings for any of the study coal base fuels.

Mass Gas Flow at the Furnace Arch: To help ensure a uniform flow pattern at the furnace exit, B&W's maximum mass flow at the base of the arch is 4000 lb/ft^2-hr. If that level is obtained, our experience indicates gas side imbalances are minimized. At 70 percent of the original MCR, the mass flow limit is not exceeded for any of the fuels studied.

Furnace exit gas temperature (FEGT)

To keep the heating surfaces clean in the areas of the upper furnace and at the inlet to the convection pass, the furnace should be designed so that it absorbs sufficient heat without exceeding the maximum exit gas temperature permitted by the slagging and fouling classifications of the coal used. The proper selection of this temperature is based on the ash fusion characteristics of the fuel, its accurate prediction and maintenance during operation, and the required heat content in the flue gas to attain the necessary superheat/reheat absorption. The study unit was designed for a FEGT of about 2575 F multiple high velocity thermocouple (MHVT) on oil firing.

The clear side spacing in the secondary superheater is 12 in. The present-day design standards for a pulverized-coal-fired boiler would limit the FEGT entering this 12-in. side spaced surface to 2250 F MHVT for the study coal.

That temperature is too low to achieve sufficient heat absorption in the convection pass. The design final reheat temperature at high loads on pulverized coal firing will not be met with the existing heat transfer surface. If the total superheater absorption could be held constant and the side spacing opened up to 15 in., a temperature of 2340 F MHVT FEGT would be permitted for the study coal which would result in full reheat steam temperatures to be attained at 70 percent MCR level. Holding the side spacing constant at 12 in., a 2250 F MHVT maximum FEGT is recommended for the study coal. The percent-MCR corresponding to this temperature level is 62 percent for pulverized coal and coal-water mixtures. Final steam temperatures of 1005 F mainsteam and 993 F reheat were obtainable at this load with these fuels. Coal-oil mixtures could attain 66 percent MCR without exceeding the side spacing/FEGT recommendation which would result in final steam temperatures of 1005 F SH/990 F RH.

Removal of secondary superheater (SSH) surface was not studied, but would have provided several alternatives as it would have served to increase clear side spacing thereby permitting a higher FEGT and higher percent-MCR with full temperature and reduced SSH spray attemperation.

The maximum obtainable load on pulverized coal and coal-water is presently limited by the FEGT/clear side spacing constraints.

Convection pass design

Good convection pass design starts in the furnace. If the furnace becomes slagged, the flue gas temperatures in the convection pass increase and slagging will progress into the more closely spaced convection banks, where it is increasingly more difficult to control. In addition to lowering the FEGT sufficiently to prevent fouling of the heating surfaces in the convection pass, the convection pass must be designed with sufficient free-flow area between tubes to avoid excessive erosion and subsequent metal loss of the heating surfaces.

Current Babcock & Wilcox standards for pulverized-coal-fired boilers limit gas side velocities for the average erosive ash to 65 ft/sec or less in the convection pass. Previous standards (used in the 1960s) based on experience at that time limited velocities to 75 ft/sec. The erosive index for the study coal ash permitted 80 ft/sec as a reasonable velocity limit to avoid excessive erosion.

Convection pass heat transfer banks labeled SSH-A, RH-D, PSH-H and ECON-J violate current design limits to various degrees. Each bank that deviates from design will be discussed below:

1. Bank SSH-A — The existing bank depth exceeds present design limits by 9 in. The limit is related to expected maximum sootblower effective cleaning radius. The addition of sootblowers would permit this bank to be kept clear of ash buildup.
2. Bank RH-D — As with Bank SSH-A, the existing bank depth is greater than present limits by 1 ft 6 in. In addition, the predicted gas temperatures indicate the clear side spacing of 3.25 in. is 0.75 in. tighter than current design standards would permit for the study at 70 percent MCR temperature levels. Some doubt exists that Bank RH-D could be kept clear on a coal base fuel, primarily because of the depth. Two reconfigurations were studied to alleviate the problem and will be discussed. Because of the narrow clear side spacing, gas velocities in this bank at 70 percent load on coal base fuels are high at 74.4 ft/sec., but are within our maximum recommended for coal, coal-oil and coal-water mixtures and are not limiting percent-MCR.
3. Bank PSH-H — The clear side spacing of this surface violates present design standards for the temperature levels calculated on the study coal. This bank's clear side spacing of 1.5 in. is 0.5 in. less than present minimum design clearance, but

it is predicted that with additional sootblowers this bank can be kept clear of ash because the flue gas temperatures are very low entering the bank.

4. Bank ECON-J — This bank has the same problems as bank PSH-H. The clear side spacing is closer than permitted by present standards (0.5 in.), but due to the low flue gas temperatures, the lanes and surface should be cleanable with the addition of sootblowers.

Reheat Reconfiguration Discussion: The original design arrangement applied to the study coal caused concern regarding the cleanability of the tightly side-spaced RH-D surface arrangement. Two convection pass bank arrangements were studied to quantify the change effect upon cleanability and velocities.

The first iteration was explored on bank RH-D (Figure 4). This revision involved changing the original four-flow arrangement to an eight-flow arrangement. The clear side spacing was increased from 3.25 in. to 9.75 in. This revision insured cleanability and also reduced the gas velocities in the bank from 74.4 ft/sec to 55.3 ft/sec at 70 percent MCR on direct pulverized-coal firing. However, as surface was removed in this iteration, the predicted final reheat temperature was reduced to 918 F at 70 percent MCR and an unacceptable 891 F at 50 percent MCR.

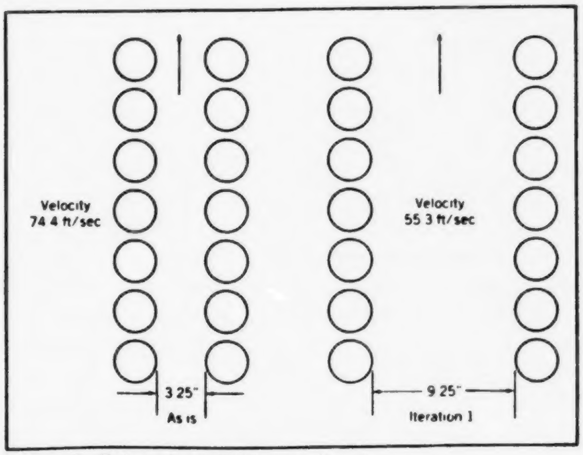

Figure 4 Reheat bank RHD- Iteration 1

A second iteration respacing this surface was made in an attempt to minimize the loss of final reheat temperature. Iteration 2 exchanged some of the primary superheater surface with additional reheat surface. The first six rows of bank PSH-F were eliminated, and in that vacated space eight rows of reheat surface were added (labeled Bank RH-E). This revision improved reheater outlet steam temperature performance and maintained the improved cleanability. At 70 percent MCR and 50 percent MCR on direct pulverized coal, final reheat temperatures of 979 F and 952 F, respectively, were attainable. Coal-oil finals of 955 F and 946 F, respectfully, and coal-water final levels of 974 F and 963 F were attainable (Figure 5).

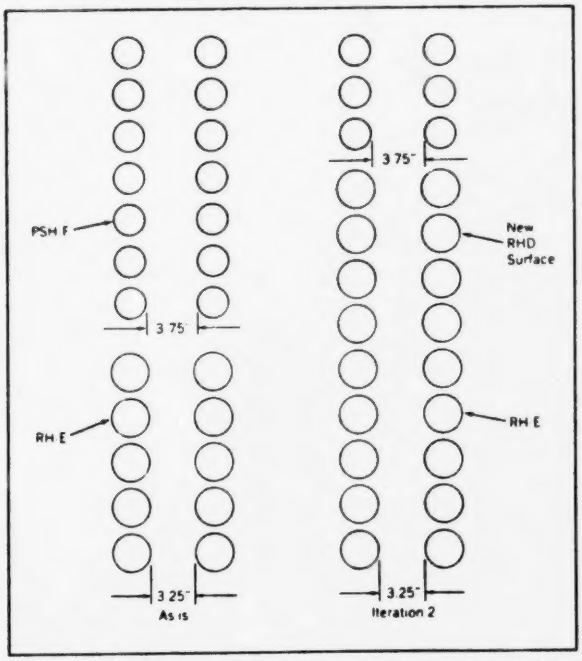

Figure 5 Reheat surface substituted for primary superheater

Flue gas weight

Presently firing oil, the study boiler was designed for a flue gas flow rate of about 1906 M lb/hr. Increased gas weights are expected with the alternative fuels and the higher gas weights will increase the heat absorption in the convection pass banks. The increase in flue gas weights is greatest in the CWM case. This aids convection heat transfer (note reheat final temperatures) and increases the potential for erosion.

Auxiliary equipment

Additional equipment must be installed to remove ash, clean the flue gases before entering the environment, prepare the fuel for burning, and keep the furnace and convection surfaces clean. The maximum practical load that these boilers can reasonably produce when firing any of the three alternative fuels will dictate the size, selection and arrangement of the auxiliary equipment required for that load. A detailed list of auxiliary equipment is presented in Table 2.

Table 2
List of equipment additions

1. 4 MPS-67N pulverizers
2. 4 PA fans
3. 8 motors for Items 1 and 2
4. Seal air piping and blowers for mills
5. Coal piping (~ 2600 ft)
6. Steel for coal piping
7. 16 circular burners with Ignitor and LC-200 controls
8. Dust collector for GR fan
9. Deasher including auxiliaries
10. Flues, ducts, expansion joints, dampers
11. Hangers
12. Damper drives
13. Furnace wall blowers
14. Convection pass blowers
15. Convection pass changes
16. Precipitator
17. ID fans
18. Material required for balanced draft conversion
19. Controls — automatic burner-mill control, safety system and changes to combustion controls for coal

Gas recirculation

The study unit utilized gas recirculation as a means of extending the reheat temperature control range. Each of the reheat surface iterations examined utilized maximum gas recirculation to improve the final temperatures. For gas recirculation fans to successfully avoid erosion damage when firing any of the proposed alternative coal fuels, means are required to separate as much of the ash entrained in the flue gases as possible before entering the fan. Various dust reduction alternatives were studied, such as dust collectors, 180° flue dropouts, and relocation of the flue gas suction to downstream of the precipitator. Due to space constraints at the study station, a dust collector was the only viable option.

Conclusions

The study concluded that:

1. It is possible to fire pulverized coal and CWMs in these boilers without major internal modifications up to a load of about 62 percent MCR. Coal-oil mixture maximum loading without major internal modifications is possible up to 66 percent MCR.
2. Sootblowers must be installed in every convection bank cavity where adequate space is available. In addition, sootblowers for the air heater and furnace will be required.
3. To achieve loads higher than 62 percent (66 percent for coal-oil mixtures), pressure part heating surface rearrangement in the convection pass banks will be required.
4. The present constraint in maximizing boiler load on the three fuel options studied, is the FEGT as it relates to the study fuels' slagging potential and unmodified clear SSH tube side spacing. The maximum load with surface revisions that can be attained on either of these fuels will be determined ultimately by the fouling effect associated with a specific FEGT. Our experience indicates a synergistic effect on furnace slagging when oil and coal are fired together. This synergistic effect has not been observed on the laboratory trials for CWMs and would not be expected to be a problem (per field experience on natural coal fuels with 30 percent moisture). The calculated and measured adiabatic flame temperatures inherent with CWMs have been measured directly in our laboratories, and those lower temperatures are reinforced by the lower NO_X generated by CWMs when compared to the parent coal. It is our expectation, based upon laboratory work and experience, that CWMs will be capable of carrying higher MCRs than coal-oil mixtures due to a decrease in furnace/convection pass slagging/fouling potentials.

Estimated costs (using 220 MW initial design) converting a potential host for permanent coal base fuel suitability — June 1981 dollars

Reviewers have suggested that the cost per kilowatt be calculated on the coal capable kilowatt base only rather than on the original 220 MW design. The original 220 MW design or 243 MW MCR capability continues to be available if oil is utilized; therefore, I have opted to retain the original approach but have indicated in parenthesis the cost per kilowatt calculated on the coal capability only.

Direct pulverized-coal conversion, including induced draft conversion and excluding any pressure part changes to increase the maximum continuous recommended loading on pulverized coal above 50 percent MCR, is estimated to cost $19,450,000 for material and erection, or approximately $88/kW ($145/kW).

Direct pulverized-coal conversion as described above, but including some convection pass pressure part surface arrangement to permit recommended loading to 62 percent MCR, is estimated to cost $22,450,000 for materials and erection, or approximately $102/kW ($149/kW). Please see Table 3 for details on what was included.

CWM conversion costs, including induced draft conversion and some convection pass pressure part rearrangement to permit recommended loadings to 62 percent MCR, is estimated to cost $17,740,000 for material and erection or approximately $81/kW ($118/kW). Please see Table 4 for details on what was included.

Coal-water mixture conversion costs as described above, but with more extensive convection pass surface rearrangement to permit recommended loadings to 75 percent MCR on coal-water, is estimated to cost $20,740,000 or $94/kW ($113/kW).

Leaving the existing oil design steam generator in place and building a new 220 MW pulverized-coal-designed unit is estimated to cost approximately $19,500,000, or approximately $87/kW. The feedwater heater string and all existing cycle equipment is assumed to be applied to the new unit. Additionally, costs for the coal storage, fuel, fuel handling, silos and support steel are not included.

Summary

Manufacturers claim demonstration quantities of coal-water slurries will be available starting in 1982 at a selling price very competitive with imported fuel oil. Burner designers and boiler manufacturers are involved in laboratory scale demonstrations that in our case appear promising in the following areas: A fuel specified to meet certain criteria is available as we have tested four mixtures manufactured from four different parent coals; laboratory work already completed by us indicates that the slagging, fouling, erosion, stability and carbon utilization characteristics of the mixtures are predictable if the parent coal is known; and an atomizer/burner design that is retrofitable is being developed for this fuel.

Finally, our studies of potential host sites indicate conversion costs from oil to coal-water are significantly less than conversion costs from oil to direct pulverized coal for selected units, fuels and client locations.

A fuel cost analysis has not been provided in this paper, but several are available and are utility-plant-specific.[2] The three elements perceived as necessary to commercialization are or shortly will be available. The firing demonstration should provide the confidence necessary to encourage retrofits, and the larger fuel

Table 3
Boiler modifications to convert
oil-design unit to fire PC

220 MWe
El Paso configuration

1. Pulverizers, PA fans, and motors
2. Piping with steel
3. Burners and lighters
4. Deasher and auxiliaries
5. Flues and ducts
6. Sootblowers
7. Convection pass modifications
8. Precipitator
9. ID Fans
10. Controls and misc.

Table 4
Boiler modifications to convert
oil-design unit to fire CWM

220 MWe
El Paso configuration

1. Burners and lighters
2. Deasher and auxiliaries
3. Flues and ducts
4. Sootblowers
5. Convection pass modifications
6. Precipitator
7. ID fans
8. Controls and misc.

demonstration preparation plants will permit the manufacturers to establish their selling prices.

B&W estimates that, in the utility market alone, approximately 20,000 MWe of boiler capacity were originally designed for coal firing but are currently firing some alternative fuel. These units could fire a CWM with a minimum amount of boiler island modifications. In addition, approximately 100,000 MWe of capacity designed for oil firing could be converted to fire a CWM with some combination of boiler modifications and derating. Finally, new steam generators which have unique transportation, siting or environmental problems may utilize CWMs as an economically attractive alternative to a direct pulverized-coal-fired boiler.

Our short term plans are to participate in a small (25 MWe) firing demonstration during 1982 and a larger (100 MWe) demonstration late in 1983 to satisfy our questions concerning the commercial applicability of coal-water mixtures.

References

1. Barsin, J. "Investigation of Coal-Water Mixtures." Presented at "Coal: Phoenix of the '80s" (June, 1981).
2. Furman, R. "Technical and Economic Feasibility of Power Plant Conversions to Coal, Coal-Oil Mixtures, and Coal-Water Slurries." Presented at "1981 Coal Technology Show" (November, 1981).

Acknowledgement

The role of EPRI in the early identification of coal water highly-loaded slurry (EPRI FP-1164) as a potential fuel for oil design power plants is recognized by the author.

TECHNICAL PAPER
NO.2

COAL-OIL-MIXTURE TEST FIRING
AT
GENERAL ASPHALT
Palmetto, Florida

December 7-10, 1981

Hauck Manufacturing Company
C. Robert Safarik
John A. Marino

Report No. SJ 1046

SUMMARY

A comparison firing of a coal-oil-mixture (COM) fuel was made against a No. 6 oil to qualitatively evaluate the Hauck Jet Burner for use on COM from the standpoint of stability, cleanliness of combustion, and atomization efficiency.

Because of test apparatus difficulties and plant commitments, the tests were not run for a sufficient length of time to totally evaluate all of these variables, but the tests were successful in demonstrating that the COM could be fired in a manner and with results very similar to that obtained firing No. 6 oil.

DISCUSSION

The tests were conducted over four days, December 7 through 10, 1981 at the General Asphalt Plant in Palmetto, Florida. This plant is a standard CMI UDM 1200 drum mix plant equipped with a baghouse. The original burner on the plant was a Hauck JBL 500 with a 24 osig air supply for firing liquid propane. Before the tests, the burner was modified to a JBO with a heavy oil manifold system for No. 6 fuel oil.

The plant is equipped with a 42-inch ID by 36-inch long brick-lined combustion chamber. The volume of the chamber is 31.7 ft^3. Inside the 7-foot diameter drum there are 40 inches of spiral flights in front of the first lifters with a volume of 128.2 ft^3 The total combustion space is 159.9 ft^3.

The material to be dried during the test program had an estimated moisture of 10%. With a material temperature of 300°F, the exhaust had run at 325°F. Previous production rate had been around 100 tons per hour. At that production rate and with the material moisture and temperature requirements, it was calculated that an input of about 46.5 million btu/hr would be required, or 335 gph of No. 6 oil. This results in a combustion volume of 290,000 btu/hr/ft^2, well within the expected range of the Jet Burner.

The No. 6 oil and the oil heater system were supplied to the job by COMCO. A sample of the No. 6 oil revealed that a temperature of 250°F was required to obtain 90 SSU viscosity.

The COM was also supplied by COMCO premixed from their plant in Tampa. The mixture had the following properties:

Composition:	50.3 coal by weight
Mean Particle Size:	32.4 micron
Moisture:	1.3%
Ash:	5.0%
Sulphur:	1.9%
HHV:	15,900 btu/lb (156,400 btu/gal)
s.g.:	1.18

The basic No. 6 oil from which the COM was blended had the following properties:

API:	11.9%
Sulphur:	2.5%
Ash:	.02%
Water:	---
Kenematic Viscosity:	196 CS @ 122°F
HHV:	151,000 btu/Gal

Difficulties were experienced with the steam heating system supplied by COMCO. In order to achieve the proper temperature of 250°F at the burner for the No. 6 oil, it was necessary to discharge oil through the atomizer until the flow rate permitted the temperature to rise from 175°F to 230°F. After ignition, which could be accomplished at 230°F, with the increase in flowrate, the temperature would reach 255°F. To hold this temperature at the burner, the discharge from the heaters had to be maintained at 285 to 290°F. In addition, an intermediate tank improvised from a 55-gallon drum had to be used as a holding tank for the recirculated oil to prevent it from being discharged back into the main tank, thus losing too much temperature.

In addition to the special heater operation, the oil lines and manifold were heat traced and wrapped in R-11 fiberglass insulation.

The skid supplied by COMCO did not have proper pressure regulation. This made start-up difficult since the 200 psig pump pressure had to be regulated by changes in bypass flow back to the main tank.

As a result of the oil handling problems, it was three days before the system was run successfully on No. 6 oil, and only one brief period of running on COM was attained on the fourth day. The time constraint resulted from the plant having to be returned to productive service on LP.

RESULTS

The base test on No. 6 oil was conducted on December 9. In order to ignite the fuel, a temperature of 230°F had to be maintained at the oil manifold. The burner was run with the high-spin atomizer and the secondary vanes at 45°.

The COM test was run using the same atomizer body with the secondary spin vanes at 20°. Difficulty was experienced lighting the COM, since a temperature of only 175°F could be reached at the burner. However, the fuel was able to be lit at this temperature after much fuel had been deposited in the ignition tile. Once ignition was achieved, the excess fuel in the chamber formed clinkers which had to be mechanically knocked out. After the burner was running for a short time, the tile and chamber ran clean.

After ignition, a fuel temperature of 235°F was maintained at the burner. The burner was fired at a rate of from 60 to 240 gal/hr.

The following observations were made while firing with the COM fuel:

1. Flame characteristics were very good and atomization was satisfactory.
2. The flame was very bushy with the COM - more so than with the No. 6 oil, even though the spin vanes were at 20° compared to 45°.
3. The flame scanner port was not purged and resulted in loss of scanner signal.
4. Adjustment of the fuel pressure showed normal burner stability response at a firing rate of about 40% open.
5. The oil pressure and temperature problems which led to difficult starting caused a deposition of black soot and carbon on the uptake at the dryer discharge. This soot cleaned up once COM was fired cleanly.
6. No change in the baghouse dust color was observed during the No. 6 or COM firing as compared to the dust during the LP firing.
7. The COM viscosity showed a sensitivity to flow and temperature as observed from the atomizer spray pattern.
8. Flame opacity was similar with No. 6 or COM.
9. The testing on the COM was done using a standard atomizer. Because of time limits, the special "cup tip" atomizer designed for this application was not tried. It is felt, however, that this new design may improve flame geometry with the COM and would be less susceptible to plugging.

The Hauck Jet Burner operated satisfactorily on COM firing into a standard CMI drum mix type dryer. No modifications were needed to either the burner or drum in order to fire COM beyond the necessary changes required to fire No. 6 oil. However, the test was not long enough to determine if any changes caused by longer term firing would be required.

Burnout of the coal particles within the flame was complete. No "sparklers" were observed going through the dryer or into the exhaust system.

Future tests on COM should consider the following recommendations:

1. Proper attention should be given to the pumping and heating system to insure proper oil temperature and pressure for light-off.
2. The scanner tubes should be continuously purged.
3. Following shutdown, the entire COM manifold should be purged with compressed air for at least 45 seconds.

COMBUSTION AND FLAME 45: 121-135 (1982)

[illegible] completed
early 1980
E. McHale

TECHNICAL PAPER
NO. 3

Combustion of Coal/Water Slurry

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Dispersions of pulverized coal in water, referred to as slurries, have been developed which are stable and fluid. They can be pumped as liquids and burned without dewatering in ordinary equipment designed for oil. The initial results of a study of the combustion performance of coal/water slurries are reported. The fuel will burn as efficiently as pulverized coal, and combustion rates approaching those of heavy oil may be ultimately achievable.

INTRODUCTION

It is possible to mix high concentrations of finely pulverized coal with water and a small amount of additive to produce a stable slurry fuel. The fuel can be burned similarly to heavy oil using combustion equipment of ordinary design. We wish to report the first results obtained in a study of the combustion behavior of this new liquid-like fuel.

Research on the concept has been ongoing for some time and involves development and combustion of slurries of coal in oil and in water. The overall study consists of two phases: Phase I, in which highly loaded coal/oil, coal/oil/water, and coal/water slurries are being formulated and tested for stability, rheological properties, etc.; and Phase II, in which good candidate slurries chosen from Phase I are burned in an experimental furnace and their combustion performance evaluated. Work on the first phase was reported at two symposia on coal-oil mixtures [1, 2]. This paper presents data on the combustion performance of the coal/water slurry only.

The slurries formulated for the study are nominally 65/35 (weight) coal to water, stabilized with modified cornstarch. Firings are conducted in a one MMBTUH experimental furnace using a specially designed swirl burner/atomizer which was developed for use with the coal/water slurry. In early tests, a small amount of gas assist was usually used, which was omitted in later tests. No change in combustion performance is found when gas is eliminated.

Combustion performance is mainly judged by measuring the amount of the combustible matter of the coal that burns and reporting this as combustion efficiency. Efficiencies approaching 90% for the results reported here are unique to the small equipment employed and are about equal to what would be expected for pulverized coal. Another figure of merit would be volumetric heat release rate which falls in the range of 35,000 Btu/ft^3/hr for the coal/water slurry, comparable to that for pulverized coal combustion. Thermochemical calculations for coal/water slurries are presented. The presence of water represents a relatively small energy penalty. A slurry made from a good coal will have a gross heating value in the range of 10,000 Btu/lb. The heat required to vaporize the water of a 65/35 mixture is about 350 Btu/lb slurry, or about 3.5%.

We are aware of other efforts in the United States and in Sweden to develop coal/water slurries, but no reports seem to be available. In Germany and Russia, slurries containing 50-60% powdered coal in water have been burned in large furnaces designed for pulverized coal firing. There are a few reports of the German work and a much larger number of Russian publications. Readers are referred to Refs. [3-5].

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DESCRIPTION OF EQUIPMENT

Furnace

A schematic of the experimental furnace and associated equipment that is being used in the program is shown in Fig. 1. A 9-ft length of schedule 10 pipe, 19.5 in. inside diameter, serves as the combustion chamber. This is positioned in a tank of 3′ × 3′ cross section through which cooling water continually flows. The water is recycled through a cooling tower at a rate of roughly 500 gph. Ports are located at the end along the top and sides of the furnace for viewing and temperature measurement. A 10-in. i.d. stack is attached near the downstream end.

Secondary air is supplied by a North American Model 32316-17-2-3 Turbo Blower which has a capacity approaching 340 SCFM, although rates this high are not used. An inlet duct, 1′ diameter × 15′ length, is attached to the blower to settle the flow, and rates through the duct are measured with a hot wire anemometer. These flow measurements serve to set approximately the air/fuel ratio during a test but are not accurate enough to be used for exact mass balances. Prior to entering the burner, the air passes through a Chromalox heater of 50 kW capacity. This is adequate to preheat secondary air to 600°F at the highest flow rate used (1000 lb/hr).

Other equipment associated with the furnace include a pump and rotometer for No. 2 oil, a metering gear pump for No. 6 oil which is preheated to about 150°F for pumping and >200°F for atomization, a compressor to supply atomizer air and swirl air, rotometers to measure both air flows, and a compressed methane supply for use when assist gas is employed, which is monitored using a critical orifice.

Stack gas anlaysis is performed by sampling with an Anderson Sampler (WP-50) at approximately isokinetic rates, and collecting the fly ash (which has a relatively high carbon content) for later proximate analysis. The filtered gas then passes through a condenser to remove water vapor and next through a Beckman nondispersive IR CO_2 Analyzer and Teledyne Model 320 Oxygen Analyzer. Carbon dioxide, carbon monoxide and also oxygen are measured with on Orsat apparatus.

The interior of the combustion chamber is lined with refractory, usually five liners of 16″ i.d. 12″ length each. These were specially fabricated by Babcock and Wilcox of high-temperature-rated (3000°F) Kaowool.

Burners

The scale of the testing of this study, 1 × 10^6 Btu hr, is at the low end for industrial oil burners. Such small units have narrow passages and orifices, and none was found that could be used with the coal/water slurry which requires a minimum opening size of about 1/8 or 3/16 in. Accordingly, we designed and built our own atomizer/burner which is shown in Fig. 2. In practice, coal/water slurry is expected to be burned in considerably larger units where many types of commercially available burners will be satisfactory. For many of the firings involving No. 2 and No. 6 oil which were burned for baseline data, a North American Model 6526-43-6 Small Heavy Oil Burner was used.

The atomizer section of the unit of Fig. 2 is an external, two-fluid atomizer requiring relatively low pressure. It appeared that to get good combustion of coal/water slurry, it would be sirable to add enthalpy to the ignition region. The best arrangement would be one that provided heat without mass addition. In a furnace, this can be accomplished by preheating the secondary air and arranging for good radiation conservation. In addition, recirculation of hot product gases would be helpful even though this represents mass addition. Swirl was favored to achieve the recirculation for the heat addition, which would also provide the benefit of flame stabilization. A swirl burner was therefore combined with the external atomizer. Neither internal air atomization nor pressure atomization was found to work with the coal/water slurry, at least on the small scale of the present study. The burner/atomizer unit operates as follows, referring to Fig. 2: Slurry from a Moyno pump flows through a 3/16″ central tube. Atomizing air enters as shown and flows through a narrow gap, impinging pheripherally on the slurry, "shearing" it, and then spraying it out into the swirl generator section of the burner proper.

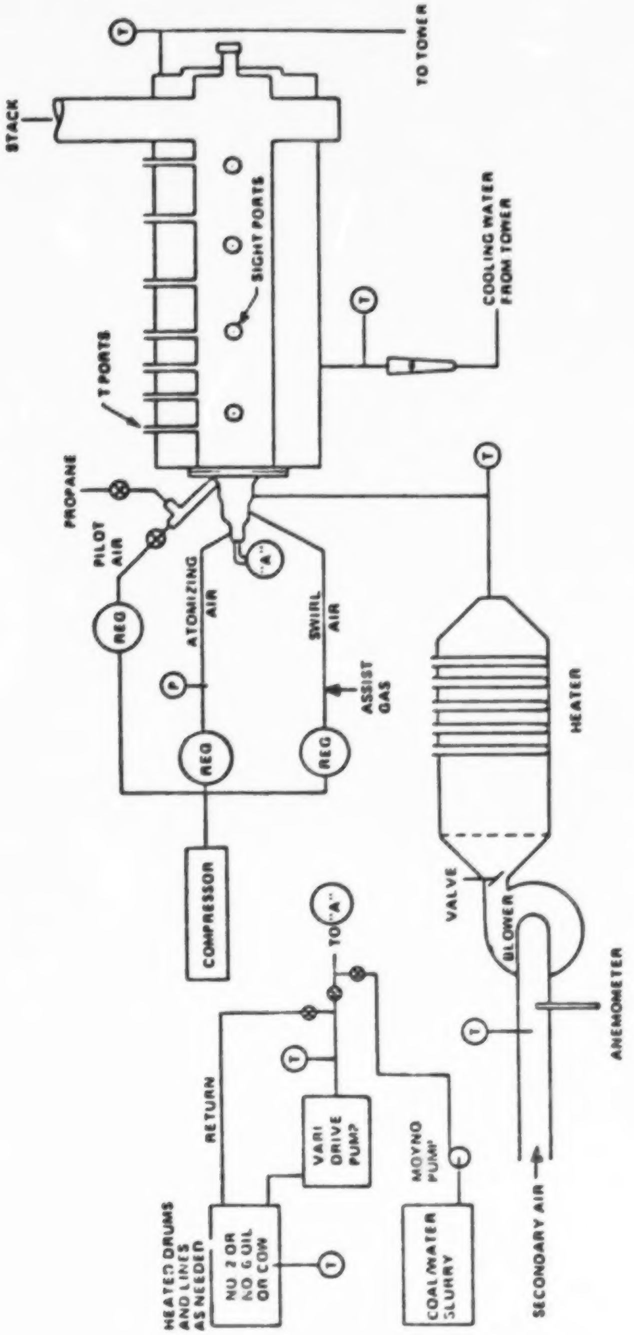
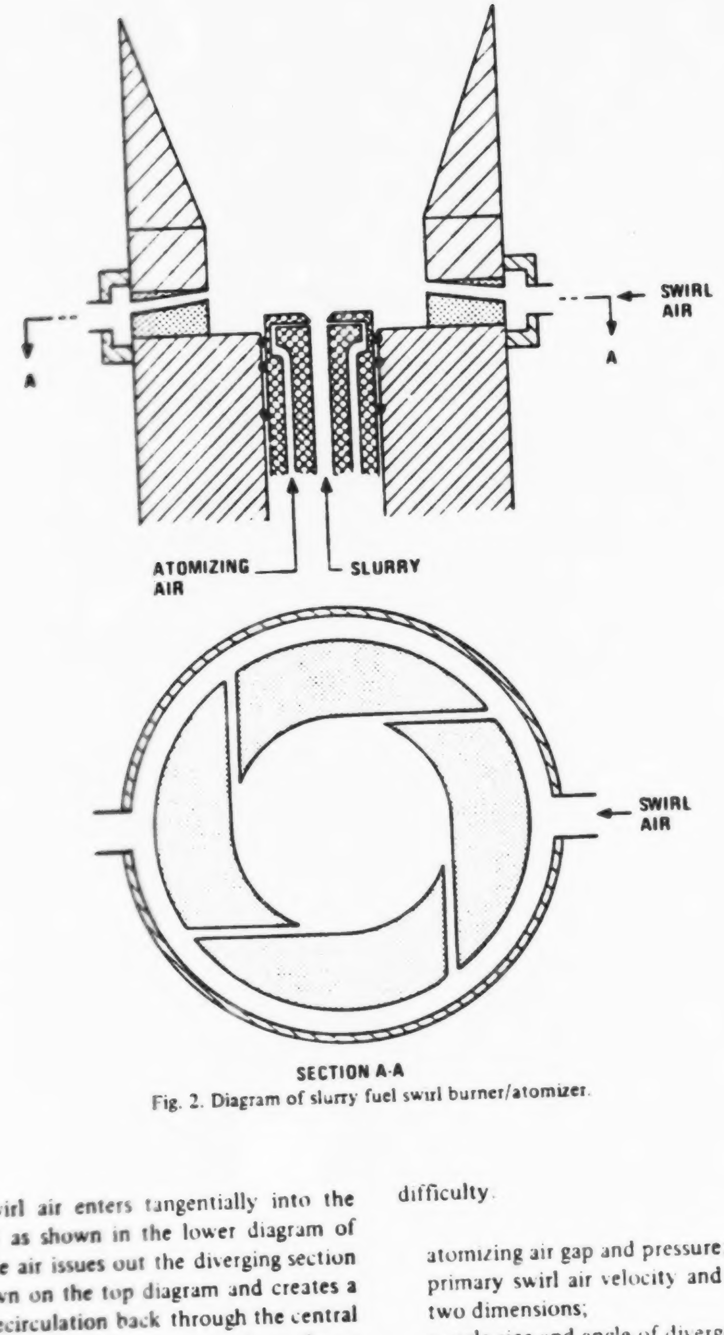

STACK
TO TOWER
T
T PORTS
SIGHT PORTS
COOLING WATER FROM TOWER
PROPANE
PILOT AIR
ATOMIZING AIR
"A"
SWIRL AIR
REG
P
ASSIST GAS
COMPRESSOR
HEATER
VALVE
BLOWER
ANEMOMETER
SECONDARY AIR
TO "A"
RETURN
VARI DRIVE PUMP
MOYNO PUMP
HEATED DRUMS AND LINES AS NEEDED
NO 2 OR NO 6 OIL OR COW
COAL/WATER SLURRY

Fig. 1. Schematic of experimental furnace facility. (T = thermocouple; Reg = pressure regulator).



SECTION A-A

Fig. 2. Diagram of slurry fuel swirl burner/atomizer.

Primary swirl air enters tangentially into the burner throat as shown in the lower diagram of the figure. The air issues out the diverging section (6" o.d.) shown on the top diagram and creates a vortex with recirculation back through the central region. It was designed to be versatile as far as experimentation is concerned with the following parameters being variable with relatively little difficulty.

atomizing air gap and pressure;
primary swirl air velocity and angle of entry in two dimensions;
nozzle size and angle of divergence;
position of the atomizer unit within the burner throat.

Swirl number for the burner is estimated to be in the range of 2-3, based on Ref. [6].

Secondary air enters around the outside of the diverging nozzle of Fig. 2 through an annular diffuser of 1/4" gap (not shown). Two styles of diffusers are employed–one in which the secondary air issues into the furnace with only axial flow velocity, and another in which swirl is imparted. The swirl is created by bringing the secondary air into the diffuser tangentially. As will be seen later, the swirl of the secondary air greatly improves slurry combustion. Operating conditions typically are: atomizing air pressure 20 psig with flow of 25 lb/hr; primary swirl air flow of 30 lb/hr; secondary air flow of 500 lb/hr. The methane-assist gas flow rate when used is in the range of 4 lb/hr and the gas is mixed with primary swirl air prior to entering the burner.

The value of swirl in pulverized coal combustion has been demonstrated by Beer and Chigier [7] in work performed at the Ijmuiden Laboratories of the International Flame Research Foundation. They used a burner in which swirl could be imparted to primary and secondary air. The primary air swirl was probably not comparable to that of the present work, although the results obtained with their secondary air swirler are comparable to ours. They found that as secondary air swirl strength increased, the point of maximum gas temperature shifted dramatically toward the burner, as did the point of minimum unburned carbon along the axis of the furnace. A pronounced improvement in flame stability was reported.

PROPERTIES OF COAL

The coals used to prepare the slurries were a medium-volatile bituminous of relatively high ash content (referred to as Dickerson) and a high-volatile of low ash (Kentucky). Analyses are based on standard ASTM methods; see Table 1.

The exact composition of the coal/water slurry made from Dickerson coal was 65% dry coal, 34% water, and 1% hydroxypropylated cornstarch, which served as stabilizer. The slurry of Kentucky coal was 62% dry coal, 37% water, and 1% starch. In order to obtain the high coal loading in the slurries, a bimodal particle size blend was used which consisted of a 55/45 mixture of coarse-to-fine grind. The fine grind was approximately 90% minus 200 mesh and the coarse was 100% minus 50 mesh. Figure 3 shows typical particle size distribution curves for the coarse and fine grinds and for the 55/45 blend. The mass mean diameter of the blended mixture was 53 μ. The specific gravity of the coal/water slurries was approximately 1.25 and viscosity was 800 cp at a shear rate of 3000 $\sec^{-1}$. It is notable that the particle blend used in the coal/water slurry produced a distribution of 55% minus 200 mesh (74 μ). This represents particle sizes that are greater than usually used in pulverized coal combustion.

In the course of the study a number of thermochemical computations have been performed for slurry and oil fuels and certain of these that are related to coal/water slurries are presented in Figs. 4 and 5.

TABLE 1

Dickerson	
Proximate–Dry Basis	
Ash	14.67%
Volatile	24.24%
Fixed carbon	61.09%
Sulfur	1.01%
Gross heat value	12,919 Btu/lb
Ultimate–Dry Basis	
Carbon	74.01%
Hydrogen	4.46%
Nitrogen	1.32%
Chlorine	0.13%
Oxygen (diff.)	4.40%
Kentucky	
Proximate–Dry Basis	
Ash	6.19%
Volatile	35.00%
Fixed carbon	58.81%
Sulfur	0.55%
Gross heat value	14,109 Btu/lb
Ultimate–Dry Basis	
Carbon	79.25%
Hydrogen	5.20%
Nitrogen	1.69%
Chlorine	0.20%
Oxygen (diff.)	7.04%

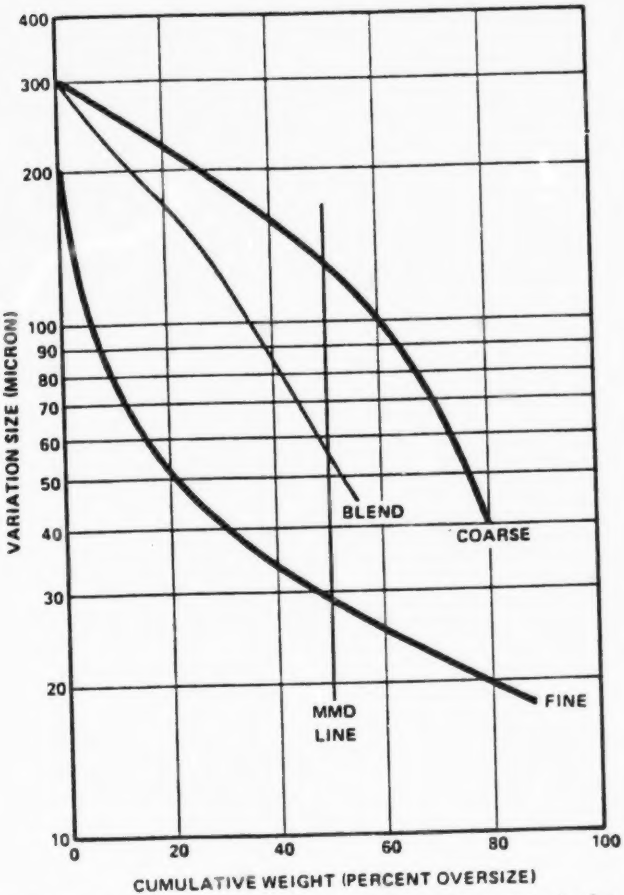


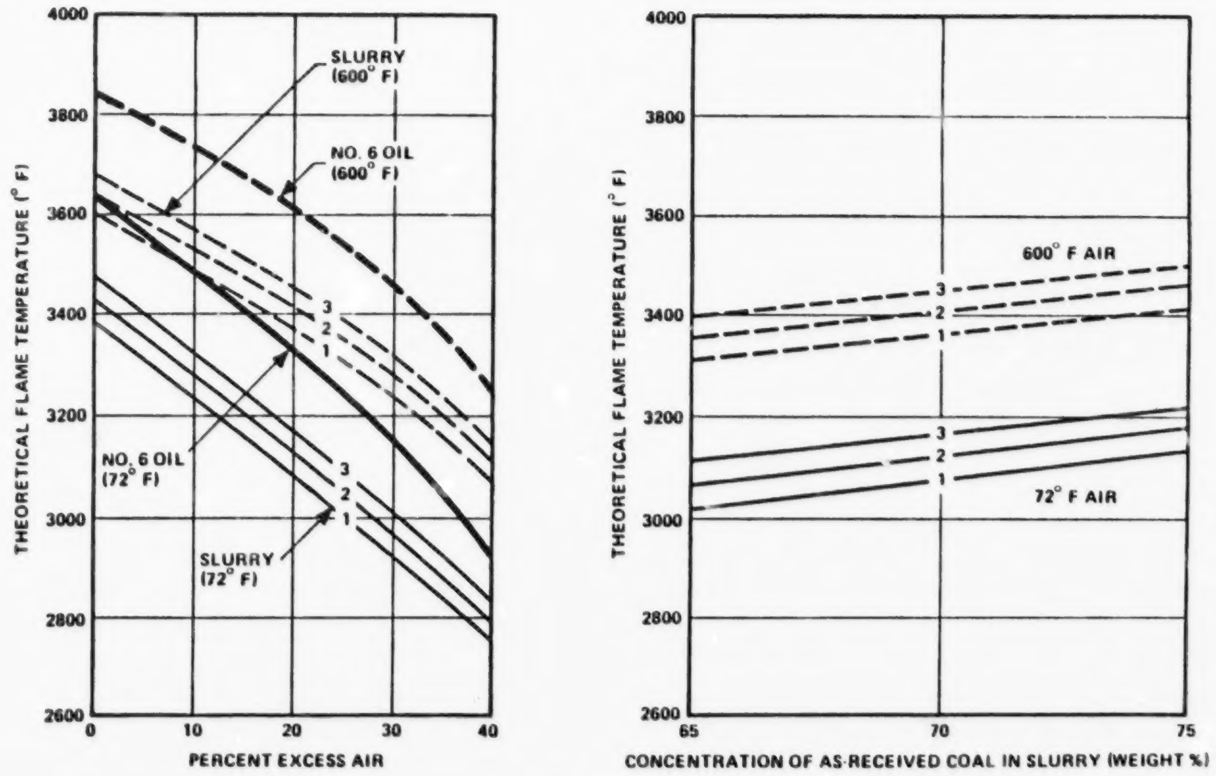
Fig. 3. Particle size distribution of pulverized coal used to prepare slurries.

Three different coals that were used for various slurries were considered (identified on the plots as 1, 2, 3), encompassing three ash contents. The analyses are listed in Table 2 together with the analysis of the No. 6 oil which was included for comparison. (The Kentucky coal was not included in these computations.)

The ash was assumed in the calculations to consist of an equal molar mixture of Al_2O_3 and SiO_2 with a composite heat of formation of −837 Kcal/mole.

Adiabatic flame temperatures calculated from the Atlantic Research thermochemical code are shown in Fig. 4. JANNAF thermodynamic data were used in all cases. In Fig. 4a, temperatures are plotted versus excess air for the three coals at two different values of secondary air preheat temperature. Typically the temperatures are approximately 200°F lower than those for No. 6 oil. In Fig. 4b, it can be seen that a 10% increase in coal loading of a slurry from 65 to 75% by weight produces approximately 100°F increase in theoretical flame temperature.

It may be pointed out that the water that is incorporated into the slurry represents a relatively small energy penalty to the fuel. This is apparent if one considers typical enthalpy values involved. A good bituminous coal will have a gross calorific



(a) (b)

Fig. 4a. Plot showing adiabatic calculated flame for 70% coal/water slurries of three coals at secondary air temperature of 72° and 600°F. No. 6 oil is shown for comparison. 4b. Plot of calculated temperature as a function of coal loading in slurry at 20% excess air.

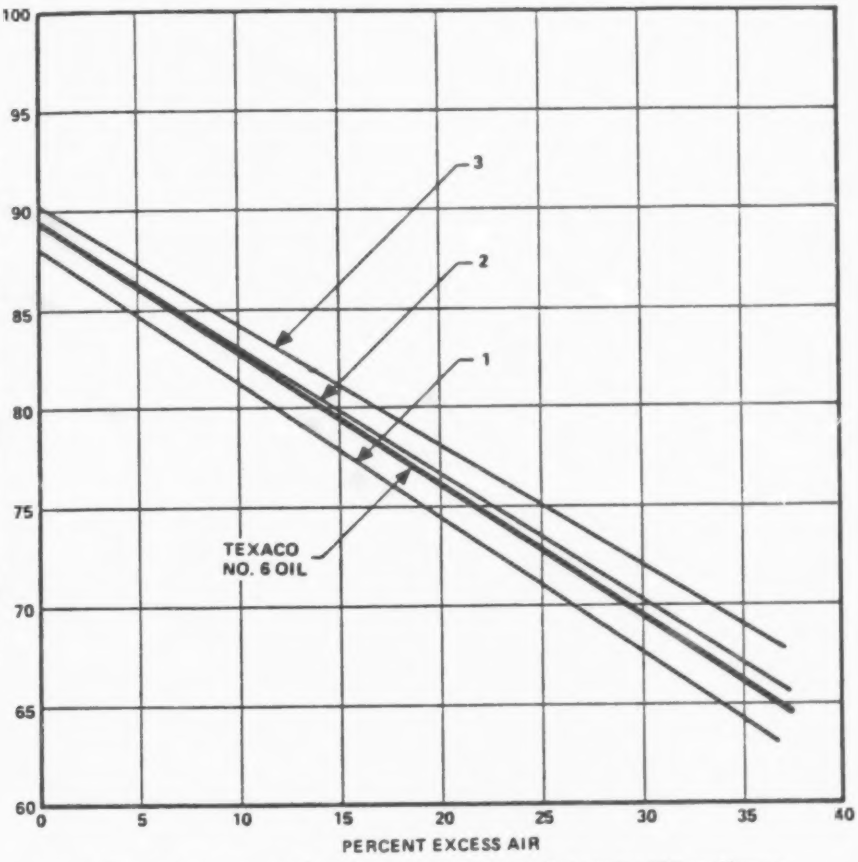


Fig. 5. Plot of heat content of product gas on a volumetric basis for 70% coal/water slurries of three different coals. Secondary air temperature 72°F. Oil shown for comparison.

value in the range of 14,000 Btu/lb on a dry basis. In a slurry of 70% loading, the coal will bring of the order of 10,000 Btu to a pound of the slurry. The heat of vaporization of water is close to 1000 Btu/lb, so the 30% water will require about 300 Btu for vaporization, which heat is not recovered. The energy penalty, therefore, of the water is of the order of 3% in a coal/water slurry fuel.

A significant consideration if coal/water slurry is to be substituted for heavy oil would be the heat content of combustion gases on a volumetric basis. The size and spacings of boiler tubes are based to a considerable extent on this factor. Any substantial change in the volumetric enthalpy content of product gas would affect heat transfer in steam generators. In Fig. 5 is plotted the available heat in the combustion gases of 70% slurries of the three coals. It can be seen that these compare favorably with No. 6 oil. Qualitatively the reason for the correspondence between the slurries and oil can be found in the fact that while the heat of combustion of oil on a weight basis is roughly double that of slurry, the air/fuel ratio is also about double. The available heat in terms of Btu/ft^3, for

TABLE 2

Proximate Analysis of Coals–As Received

	1 "Dickerson"	2 "PHS-361"	3 "Elkhorn"
Moisture	2.15%	2.9%	3.1%
Volatile matter	23.7%	35.7%	35.0%
Ash	14.35%	7.7%	3.0%
Fixed carbon	59.8%	53.7%	58.9%
Sulfur	0.99%	1.10%	0.60%
Gross heat value (Btu/lb)	12,641	13,460	14,290

Ultimate Analysis–Dry Basis

	1	2	3
C	74.01%	77.70%	79.13%
H	4.46%	5.06%	5.66%
N	1.32%	1.50%	1.50%
S	1.01%	1.09%	0.61%
O	4.40%	6.71%	10.00%
Ash	14.67%	7.93%	3.10%

No. 6 Oil Analysis

C	84.64%
H	11.84%
N	0.02%
S	0.17%
O	2.78%
Gross heat value	18,402 Btu/lb

example, is then about comparable for the two fuels since oil with the higher calorific value has to heat a greater amount of product (mostly nitrogen).

RESULTS

The slurries were found to burn satisfactorily, and the many variables associated with the burner, furnace, etc., were investigated and optimized in preliminary tests. The burning performance was characterized by measuring combustion efficiency and examining this dependent variable as a function of air/fuel ratio.

There are two ways in which combustion efficiency can be obtained. One is by knowing the total throughput of all air and fuels and then measuring the carbon dioxide or oxygen content of the stack gas. This method could not be employed in the present study because the flow rates of air and fuel could not be measured accurately enough.

The second method by which combustion efficiency can be determined and which was employed in this study is by analyzing the unburned solid residue and using the coal ash as a tracer. (As a simple illustrative example, if a coal with 10% ash were to burn with 80% efficiency, the ash content of the residue would be 35.7%.) In this case, the combustion efficiency (CE) refers to the weight of combustible matter (CM) that is consumed. A general formula can be written relating weight %CE and ash:

$$\%\mathrm{CE}_{\mathrm{wt}} = 100 - \frac{\%\text{ ash in coal}}{1 - (\%\text{ ash in coal}/100)} \times \left(\frac{100}{\%\text{ ash in residue}} - 1\right). \qquad (1)$$

There are two sources of error in this method. First, it is not the ash content that should be considered but rather the mineral matter content, the latter typically running somewhat greater than the coal ash. However, this carries over as a negligible error for present purposes. The second source of error is also rather small and results from the fact that the empirical formula of the combustible matter changes during burning. Since the hydrogen content during burning proportionately decreases relative to carbon, and since hydrogen has a very high heat of combustion on a weight basis, any combustion efficiency value cited on a weight basis will be less than that on an energy-released basis. However, by far the greatest source of er was found to be not the problems with min matter or empirical formula change, but rather that of obtaining a representative sample of unburned residue. We found that the combustible matter content of the residual ash varied widely between fly ash and bottom ash and also with the location of deposit of the bottom ash in the furnace.

The two combustion efficiencies (weight and energy) can be related through the heating value (HV) of the unburned residue, given by

$$\mathrm{HV}_{\mathrm{residue}} = \frac{\mathrm{HV}_{\mathrm{coal}}\,[1 - (\%\mathrm{CE}_{\mathrm{en}}/100)]}{\%\mathrm{CM}[(1 - (\%\mathrm{CE}_{\mathrm{wt}}/100))] + (\%\ \text{ash in coal}/100)}, \tag{2}$$

which expresses the energy left in the residue per weight of remaining residue. Rearranging,

$$\%\mathrm{CE}_{\mathrm{en}} = 100 - \frac{100\mathrm{HV}_{\mathrm{residue}}}{\mathrm{HV}_{\mathrm{coal}}} \times \left[\left(1 - \frac{\%\mathrm{CE}_{\mathrm{wt}}}{100}\right)\left(1 - \frac{\%\ \text{coal ash}}{100}\right) + \frac{\%\ \text{coal ash}}{100}\right]. \tag{3}$$

Once combustion efficiency is determined from ash proximate analysis, the amount of excess air that was present during a firing can be determined from stack gas analysis for O_2 and/or CO_2. This procedure is illustrated using the Dickerson coal of the present study which has the empirical formula $CH_{0.718}N_{0.015}S_{0.0051}O_{0.0446}$. From the chemical equation

$$\begin{aligned}(\mathrm{CE})\mathrm{CH}_{0.718}\mathrm{N}_{0.015}\mathrm{S}_{0.0051}\mathrm{O}_{0.0446} &+ (\mathrm{ER})1.162\mathrm{O}_2 + (\mathrm{ER})4.400\mathrm{N}_2 \\ &\rightarrow (\mathrm{CE})\mathrm{CO}_2 + (\mathrm{CE})0.359\mathrm{H}_2\mathrm{O} \\ &+ (\mathrm{CE})0.0051\mathrm{SO}_2 + [(\mathrm{ER})4.400 \\ &+ (\mathrm{CE})0.0075]\mathrm{N}_2 + (\mathrm{ER} - \mathrm{CE})1.162\mathrm{O}_2, \end{aligned} \tag{4}$$

where ER is air equivalence ratio and CE is fractional combustion efficiency, the ER from stack oxygen analysis is given as (on a dry basis, neglecting SO_2 and fuel-produced N_2):

$$\mathrm{ER} = \frac{\mathrm{CE}(0.162\%\mathrm{O}_2 - 116.2)}{5.562\%\mathrm{O}_2 - 116.2}. \tag{5}$$

When methane assist is used it must be taken into account in Eq. (4).

The results of tests with the 65/35 slurry of Dickerson coal are presented in Table 3 where most of the entries are self-explanatory. These runs were all made using the secondary air diffuser which injected air with only an axial velocity component. The assist gas is given as weight percent of the slurry. The percent excess air is given relative to total slurry input. The calculated theoretical flame temperatures are based on the actual amount of fuel that burned using energy-released combustion efficiencies.

Combustion efficiencies based on energy release are shown as a function of excess air in Fig. 6 as solid points for the data of Table 3. At about 20% excess air, approximately 75% of the energy of the combustible matter of the coal is released. No correlation was found between combustion efficiency and the amount of assist gas.

TABLE 3

Summary of Results of Firings of (Dickerson) 65/35 Coal/Water Slurry without Secondary Air Swirl

Test no.	Slurry flow rate (lb/hr)	Firing rate (MMBTUH)	Secondary air temperature (°F)	Assist gas CH_4 (wt %)	% Ash in bottom residue	% C.E. (weight)	% C.E. energy	Vol % O_2 stack	% excess air	Vol % CO_2 measured	Vol % CO_2 theoretical	Op. pyr. furnace temperature (°F)	Calculated theoretical flame temp. (°F)
1	62	0.51	570	9.7	49.2	82	85	10.3	76	8.4	8.7	–	2535
2	84	0.70	550	4.9	37.7	72	75	5	−3	13.9	13.7	–	3090
3	53	0.44	570	7.9	43.0	77	80	8	32	8.8	9.0	–	2810
4	86	0.71	600	3.2	30.0	60	62	8.5	3	11.3	10.8	2200	2640
5	63	0.52	550	6.6	23.6	44	46	4.7	−38	13.2	13.0	–	2840
6	126	1.04	600	3.3	25.9	51	52	5.5	−31	–	12.9	–	2865
7	76	0.63	600	5.0	26.8	53	54	5.5	−21	–	12.5	–	2800
8	80	0.66	600	5.2	38.8	73	74	9.6	46	8.7	9.5	2190	2510
9	82	0.68	600	5.1	40.6	75	78	8.8	37	–	10.2	2050	2680
10	72	0.60	600	5.0	39.7	74	76	11.0	69	–	8.3	2130	2350
11	78	0.65	600	0.0	38.8	73	75	8.0	18	–	11.4	2150	2730

The results of additional tests with slurries of Dickerson coal plus results of slurries made with the Kentucky coal are presented in Table 4 and shown as open points in Fig. 6. There are several differences between the data of Tables 3 and 4. First, the tests of Table 4 were performed with the secondary air swirl diffuser. This accounts for most of the increase in combustion efficiency that was achieved (apparent in Fig. 6). The second difference is that combustion efficiencies for the tests of Table 4 were obtained by weight averaging the ash content of both bottom and fly ash, whereas for the data of Table 3 only bottom ash was analyzed. Since fly ash usually had a higher ash content than bottom ash, the higher efficiencies of the open point data are partly due to this change in procedure. As best as we are able to estimate, 80% of the increase in combustion efficiency, represented by the dashed line of Fig. 6 over the solid line, was caused by addition of the secondary air diffuser, with about 20% being due to the inclusion of fly ash analysis along with bottom ash. A third important difference is that all the data of Table 4 were obtained with no gas assist. It appears from the open point data of Fig. 6 that slurry of the high-volatile Kentucky coal produced somewhat greater combustion efficiencies than slurry of the medium-volatile Dickerson, by a few percentage points.

The duration of the tests was usually held to between 15 and 30 min in order to conserve slurry. In test No. 5 with the slurry of Kentucky coal, the run time was 80 min with no indication of problems. During these periods the furnace temperature level was approximately constant as measured on the refractory wall with an optical pyrometer. While these measurements (Table 3) are considerably below theoretical flame values, nevertheless they provide an indication of how the combustion is progressing during any given test because they are related to flame temperature and follow changes in it. No signficance can be attached to absolute values of the measured temperatures, as could be readily seen if one were to plot calculated and measured data. The general wall temperature level varies from test to test because the surface of the refractory has an ash or slag coating of varying degree and properties.

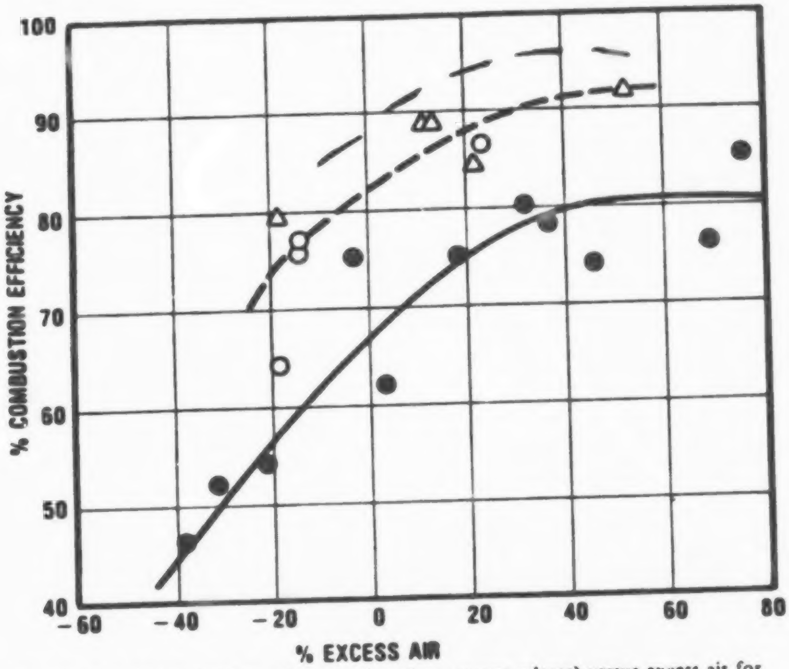


Fig. 6. Plot of combustion efficiency (based on energy release) versus excess air for tests with coal/water slurry. ● = Dickerson Medium Volatile Coal, No secondary air swirl, Bottom ash analyzed. ○ = Dickerson, Secondary air swirl, Bottom and fly ash analyzed. △ = Kentucky High Volatile Coal, Secondary air swirl, Bottom and fly ash analyzed.

The coal/water slurry burned nicely, and the combustion efficiencies attained are very reasonable for the particle size of the coal and for the small size of the furnace. A better figure of merit at present than combustion efficiency might be volumetric heat release rate, which for a typical firing rate of 700,000 Btu/hr and 85% efficiency in an approximately 17-ft^3 chamber is 35,000 Btu/ft^3/hr.

It is desirable to make a comparison between the present slurry results and those of dry pulverized coal burning. We have not performed pulverized coal firings in our furnace, so the best that can be done is comparison with data of other studies. One relevant study is that of Beer [8], who burned pulverized anthracite coal and made extensive measurements on burning performance and combustion parameters as a function of particle size and burner type. Another relevant, although less recent, study is that of Sherman [9]. For present purposes, the Sherman work seems to lend itself better to comparison with the slurry study, especially to our data without the swirl diffuser, because the coals used were bituminous covering a range of volatile and ash content, the main dependent variable measured was essentially combustion efficiency, and the scale of the furnace was much closer to ours, although still larger. In the Sherman study, a 180-ft^3 refractory wall furnace was used of $15' \times 3\frac{1}{2}' \times 3\frac{1}{2}'$. Firing rates were in the range of 2.7 MMBTUH. Based on data in his paper, a space velocity can be computed of about 0.3 sec^{-1}, or a residence time of the order of 3 sec. A comparably computed residence time for the furnace of the present study under typical conditions would be about 1.5 sec. Volumetric heat release rates in the Sherman study were about 20,000 Btu/ft^3/hr. He burned four coals of

TABLE 4
Slurry Firing Results with Secondary Air Swirl

Test no.	Slurry flow rate (lb/hr)	Firing rate (MMBTUH)	Secondary air temperature (°F)	% ash in bottom residue	% C.E. (weight)	% C.E. (energy)	Vol % O_2 stack	% excess air	Op. pyr. furnace temperature (°F)
Dickerson 65/35 slurry (8060 Btu/lb)									
1	0.66	82.4	400	40.96	75	77	2.9	−13	2198
2	0.74	91.5	360	31.02	62	64	5.3	−18	2045
3	0.76	94.1	350	39.73	74	76	3.3	−13	2160
4	0.56	69.8	400	53.37	85	86	6.8	+25	2158
Kentucky 62/38 slurry (8380 Btu/lb)									
1	0.61	72.3	400	28.26	83	84	6.9	22	2080
2	0.44	52.8	360	37.60	89	92	8.9	53	1825
3	0.81	96.5	560	23.42	78	79	1.1	−18	2178
4	0.61	72.6	570	34.58	87	88	5.0	14	2346
5	0.57	67.7	580	31.13	85	88	5.3	13	2225

various ash and volatile matter contents, and reported percentage unburned carbon as a function of particle size and excess air. When one examines the Sherman data and attempts to predict what combustion efficiency would have been obtained in his furnace in the residence time of 1.5 sec and with the coals of the present study, one arrives at a percentage in the seventies or eighties. Or, conversely, the Sherman results indicate that coal burned in pulverized form in our furnace should yield efficiencies about as found for slurry. These very rough comparisons indicate that the coal/water slurry has burned at least as well as pulverized coal would have been expected to.

MISCELLANEOUS CONSIDERATIONS

Some points of relevance to the present study are worthy of note. The first concerns data that were obtained in the course of the work that bear on the generally accepted mechanism of coal combustion. Coal is usually described as burning in three stages—first, the volatile matter is rapidly released and burns as a gas; second, the remaining char burns via surface reaction, relatively slowly; and third, the CO released in the char reaction burns in the gas phase to CO_2, also fairly rapidly. The second stage of the process is considered to be rate limiting, and can be a mass transfer controlled process (as it seems to be for particles >100 μm), or a chemical controlled process (as it apparently becomes as particle size falls below 100 μm). In the former case, efficient turbulent mixing promotes reaction, and temperature sensitivity and internal porosity dependence are low. Burn time varies as the square of particle diameter. In the latter case, the reaction is exponentially dependent on temperature, and if the internal surface area becomes great enough, the reaction can become independent of particle size. A thorough review of the subject is given by Mulcahy and Smith [10].

In the present study we have measured low CO/CO_2 ratios in the stack gases for the burning of the coal/water slurry, CO almost always being less than 0.1% and CO_2 being in the range of 10%. Thus the third stage of burning occurs as generally described. On the other hand, it appears that an

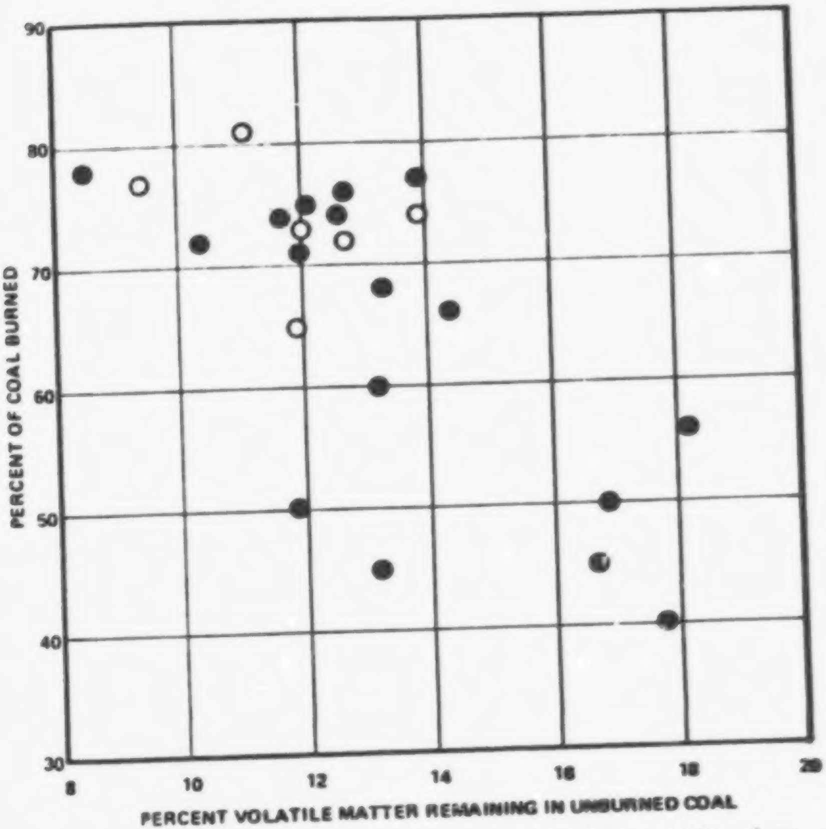


Fig. 7. Plot of volatile matter content of unburned residue (bottom ash) from slurry firings. Solid points are coal/water and open points are coal/oil/water mixtures. All data are weight percent on dry, ash-free basis. The coal was the Dickerson Medium Volatile Bituminous originally containing 28.4 percent Volatile Matter (DAF). (Two data points for C/W slurry were omitted: 5.6% VM at 67% and 23.1% VM at 83% coal burned.)

assumption of rapid volatile matter release as the first stage does not hold very well. We have collected the bottom ash from the furnace after tests and have found from proximate analyses that it still has a high content of volatile matter. This can be seen in Fig. 7, where the weight percent volatile matter in the bottom ash is shown as a function of the amount of combustible matter burned in the coal. One would expect that when, say, 75% of the total combustible matter of a coal is consumed, that the remaining unburned residue would have very low volatile content. From Fig. 7, it can be seen that in such an example, the volatile matter of the residue is in the range of about 13% (the scatter exhibited by the data is noted here). The coal was the Dickerson medium-volatile bituminous, 24.24% VM on a dry basis and 28.40% on a dry, ash-free basis.

Another way to view these results is as follows: The original coal contained 28.4% VM and 71.6% FC on a dry, ash-free basis. The unburned residue after 75% of the combustible matter was consumed contained approximately 13% VM. On a unit weight basis, therefore, the VM decreased from

0.284 to 0.0325 (13% of 0.25), which is close to a 90% loss, while the FC, which was 87% of the residue, decreased from 0.716 to 0.2175 (87% of 0.25), or roughly 70%. The rate of release of volatile matter therefore is faster than the rate of consumption of fixed carbon, but not greatly so.

The results from the Kentucky high-volatile coal exhibited a similar pattern (not plotted). The percentage volatile matter on a dry, ash-free basis of the original coal is 37.3%. The unburned bottom residues of the five tests had volatile matter contents, on the same basis, of between 11.4 and 26.4% for coal burnout between 78 and 89%.

The early time-temperature history of burning coal in the coal/water slurry is different from what it would be in particle experiments or in pulverized coal combustion. However, it appears that this is not responsible for the behavior that is evident in Fig. 7 because results of tests of a coal/oil/water mixture, burned in separate experiments, fall into the same pattern. In the COW case, the early time-temperature history is completely different than that of C/W slurry, probably resembling that for pulverized coal.

Samples of bottom ash were examined by a scanning electron microscope and were found to consist mostly of rounded particles of about 100-300 μ in diameter, which have considerable macroporosity and appear to be practically hollow inside, as if they had swollen. Pore openings were approximately 2-20 μ. There was no evidence of agglomeration, although this cannot be definitely ruled out. The model of a coal particle burning with progressively decreasing diameter does not hold in the present case. Based on comments made above about mass transfer controlling burning time of particles greater than about 100 μ, it would appear that increased turbulence in pulverized coal burning would produce higher combustion rates.

CONCLUSIONS

Stable, fluid dispersions containing 62 and 65% pulverized bituminous coal in water have been burned in a nominal 1×10^6-Btu/hr furnace in a manner similar to oil. A burner/atomizer was designed for the small-scale firings, which performed very well. The benefit of swirl was shown by tests in which significant improvement in carbon burnout was realized by imparting a high degree of swirl to the secondary air. The coal/water slurries burned at about the same rate that dry pulverized coal would have been expected to. An interesting finding of the study was that even after large amounts of coal burnout have occurred, the remaining unburned material has a relatively high percentage of volatile matter. This does not appear to be related to the presence of water in the fuel. Another feature of the material that had not completely burned and was recovered as bottom ash is that the particle size was quite large and possessed considerable macroporosity.

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The interior of the combustion chamber is lined with refractory, usually five liners of 16" i.d. by 12" length each. These were specially fabricated by Babcock and Wilcox of high-temperature-rated (3000°F) Kaowool.

BURNERS. For many of the firings involving No. 2 and No. 6 oil which were burned for baseline data, a North American Model 6526-43-6 Small Heavy Oil Burner was used. This unit provides internal air atomization of the fuel at an atomizer pressure of 15 psig. The atomizer nozzle ejects the fuel-air mixture through an approximately 1/4" diameter annular opening of about 400 microns annulus gap. The secondary air is brought into the furnace through a diffuser which consists of eight 5/8" tubes positioned around the atomizer nozzle. This burner was not found to be very satisfactory for coal/oil/water slurry inasmuch as it clogged within a few minutes. It was not satisfactory at all for coal/water slurry. Considerable effort was devoted to examining existing atomizers and burner designs and ultimately to developing a new unit for use with coal/water slurry, and the results of this work are described below.

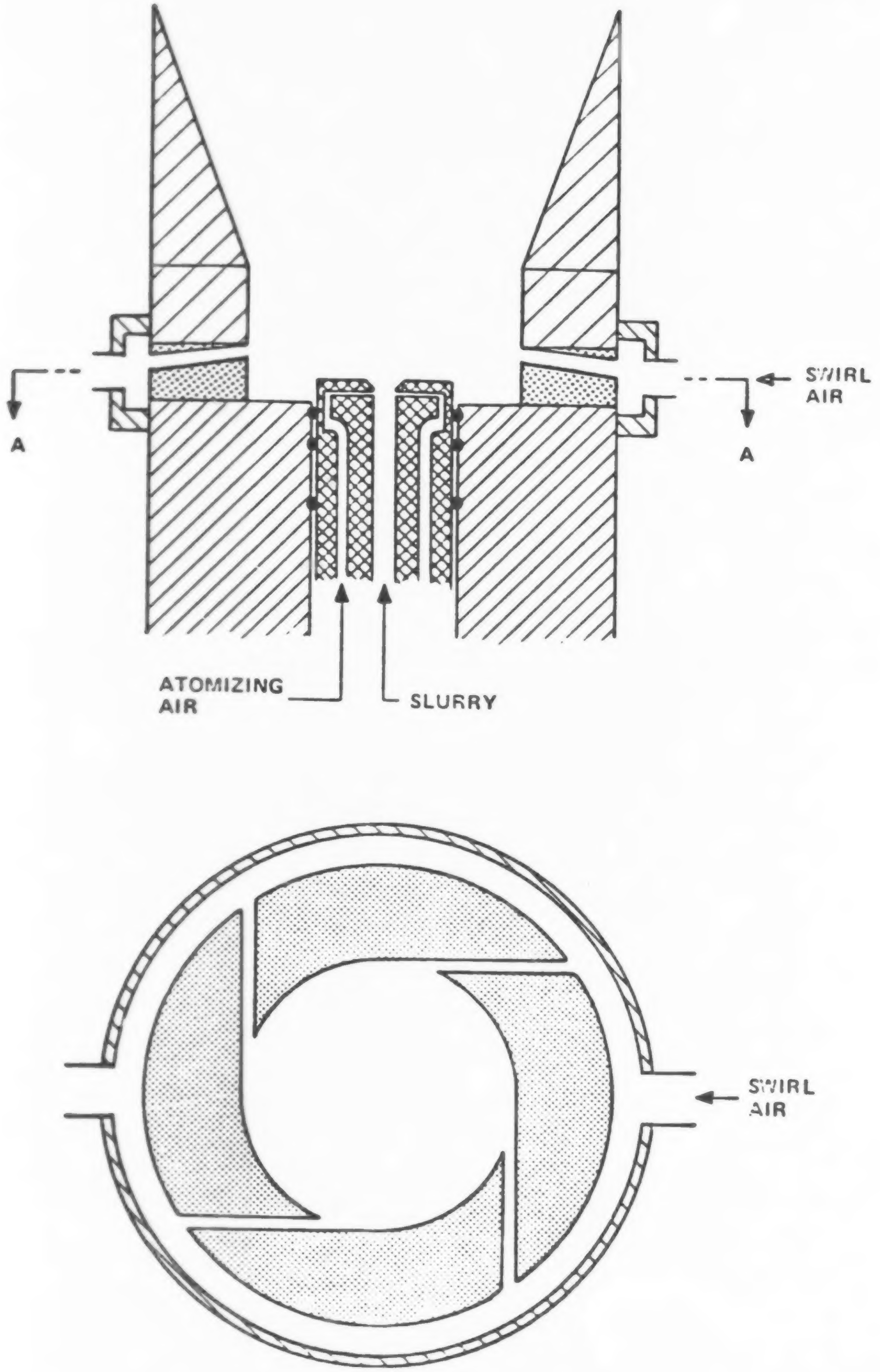
It was learned by experimentation that most if not all available atomizers are not suitable for coal/water slurry. Pressure atomization cannot be used. Any type of atomizer that requires the slurry to flow through narrow passages (less than about 3/16") or around sharp bends is also not usable. Bridging of the slurry and blockage will occur. Dozens of designs were examined and several types purchased and tried. One was an industrial Binks spray type which falls in the class of an "air mixing" atomizer. This produced good atomization but very high spray flow velocity. A coal flame probably could not be stabilized at this velocity. In addition, after operating a short time, it would become clogged with caked coal deposit in the (relatively large) tube through which the slurry flowed. This atomizer was therefore not satisfactory.

The second unit tested was a sonic device called "Sonicore Atomizer," reputed to show outstanding performance in oil burning. This too was unsatisfactory for a number of reasons. When used in the normal way the fuel must flow through too narrow a set of passages. The manufacturer claimed it could be used in reverse fashion by putting fuel through the (large, traight) air inlet and air thorugh the normal fuel inlets. This arrangement did not even work well with No. 2 oil, much less coal slurry. In addition, the atomizer has a small cup ("resonant cavity") which is attached just beyond the point where flow separation starts. As the air impinges on the cup, acoustic waves are set up which enhance the atomization. When used with coal/water slurry, this cup and the entire outlet region of the atomizer soon become clogged with caked coal deposit.

Having satisfied ourselves that no commercially available atomizer would work, we designed and built our own "shear" atomizer. This is shown as part of Figure 3 and will be described shortly.

It appeared that in order to get good combustion of coal/water slurry it would be desirable to add enthalpy to the combustion zone. The best arrangement would be one that provided heat without mass addition. In a furnace this can be accomplished by preheating the secondary air and arranging for good radiation conservation. In addition, recirculation (for example, by a vortex) of hot product gases would be helpful even though this represents mass addition. A swirl burner that produced high swirl strength was favored to achieve the recirculation. A small swirl burner was designed and made (equivalent to about 100,000 BTU/hr). This was combined with the atomizer and tested also. The best performance that was achieved with the small burner was a "good looking" coal/water slurry flame in the open air that burned for about one minute in the best test before the swirl generator section blocked up. It required methane mixed with the swirl air to sustain the slurry flame. (The amount of methane was equivalent to about 10% of the weight of slurry.) There were no diagnostics used in the open air test to measure efficiency of burning. Both the clogging and the need for methane appeared to be due to the small size of the burner which was only 1-1/2" outside diameter referring to Figure 3.

These first tests led to the design of a combined atomizer/burner that is shown in the figure with the atomizer shown in cross-hatching. Slurry from a Moyno pump flows through a 1/4" central tube. Atomizing air enters


SWIRL AIR
A
A
ATOMIZING AIR
SLURRY
SWIRL AIR

SECTION A-A

Figure 3. Diagram of Slurry Fuel Swirl Burner/Atomizer.

as shown and flows through a narrow gap (typically 0.010 to 0.015"), impinging peripherally on the slurry, "shearing" it, and then spraying it out into the swirl generator section of the burner proper.

Swirl air enters tangentially into the burner throat. The lower diagram is a top view illustrating how air enters and has swirl imparted to it. The air issues out the diverging section (6" o.d.) shown on the top diagram and creates a vortex with recirculation back through the central region. It was designed to be versatile as far as experimentation is concerned. The following parameters can be varied with relatively little difficulty:

Atomizing air gap and pressure.
Swirl air angle of entry in two dimensions and velocity.
Nozzle size and angle of divergence.
Position of the atomizer unit within the burner throat.

A method of characterizing the burner is by use of the nondimensional swirl number, defined in (4) as

$$S = \frac{G_o}{G_x R}$$

where G_o is the axial flux of the angular momentum, G_x is the axial flux of the linear momentum, and R is the exit radius of the burner nozzle. Using approximation procedures recommended in (4), a swirl number in the range of 2 - 5 is estimated. A value of 0.6 approximately represents the point where vortex recirculation is established.

Secondary air enters around the outside of the diverging nozzle of Figure 3 through an annulus of 1/4" gap. Operating conditions typically were: atomizing air pressure 20 psig with flow of 25 lb/hr; swirl air flow of 30 lb/hr; secondary air flow of 500 lb/hr. The methane assist gas flow rate was in the range of 4 lb/hr and the gas was mixed with swirl air prior to entering the burner. The linear velocity of the secondary air as it entered the furnace was in the range of 100 ft/sec, compared to about 200 ft/sec through the North American burner inlet when it operated at comparable capacity.

III. PROPERTIES OF FUELS

Analyses of the fuels used in the program were performed by Commercial Testing and Engineering Co. of Norfolk, Virginia, using Standard ASTM Methods. The fuel oils gave the following analyses:

No. 2 Oil

Gravity:	
Specific at 60/60°F	0.8423
Lb per gal at 60°F	7.013
°API	36.5
Heating Value:	
BTU per lb	19,526
BTU per gal at 60°F	136,940
Sulfur Content, Bomb Method	0.27% by wt.
Pour Point	20°F below 0
Cold (Solid) Point	20°F below 0
Viscosity at:	
100°F Saybolt Furol	34.9 Seconds
100°F Kinematic	2.68 Centistokes

	% Weight
Carbon, C	86.13
Hydrogen, H	12.95
Sulfur, S	0.27

No. 6 Oil

Gravity:	
Specific at 60/60°F	0.9433
Lb per gal at 60°F	7.856
°API	18.5
Heating Value:	
BTU per lb	18,402
BTU per gal at 60°F	144,570
Sulfur Content, Bomb Method	0.60% by wt.
Viscosity at:	
100°F Saybolt Furol	57.3 Seconds
100°F Kinematic	119 Centistokes

	% Weight
Carbon, C	84.64
Hydrogen, H	11.84
Nitrogen, N	0.02
Sulfur, S	0.72
Ash	0.02
Oxygen, O (diff)	2.76

The coal was a medium volatile bituminous of relatively high ash content and was used for both the COW and coal/water slurries.

Coal Analysis

Proximate - Dry Basis

Ash	14.67%
Volatile	24.24%
Fixed Carbon	61.09%
Sulfur	1.01%
Gross Heat Value	12,919 BTU/lb

Ultimate - Dry Basis

Carbon	74.01%
Hydrogen	4.46%
Nitrogen	1.32%
Chlorine	0.13%
Sulfur	1.01%
Ash	14.67%
Oxygen (diff.)	4.40%

Fusion Temperature of Ash

	Reducing	Oxidizing
Initial Deformation	2620 °F	2700+ °F
Softening (H=W)	2700+°F	2700+ °F
Softening (H=1/2W)	2700+°F	2700+ °F
Fluid	2700+°F	2700+ °F

H = Cone Height
W = Cone Width

Free Swelling Index

#5-1/2

The coal/oil/water slurry had a nominal composition by weight of 50/40/10. The oil used was No. 6 of the analysis just given. The coal was pulverized in a hammermill and the particle size distribution corresponded to the curve labeled "Fine" in Figure 4. The slurry also contained 1% of the emulsifier Brij 35, hence the exact COW ratio was 49.5/39.6/9.9. The specific gravity of the COW slurry was 0.98 at 70°F.

The coal/water slurry had a nominal composition of 65/35 which should be adjusted to allow for the presence of one percent of hydroxypropylated corn starch which served as the stabilizer. In order to obtain the high loading, a bimodal particle size blend was used which consisted of a 55/45 mixture of coarse-to-fine grind. The fine grind was approximately 90% minus 200 mesh and the coarse was 100% minus 50 mesh. Figure 4 shows typical particle size distribution curves for the coarse and fine grinds and for the 55/45 blend. The mass mean diameter of the blended mixture was 53 microns. The specific gravity of the coal/water slurry was 1.25 and viscosity was 800 cp at a shear rate of 3000 sec^{-1}. Considerable thermochemical computations were performed for coal/water mixtures, some of which are presented in the Appendix A. It is notable that the particle blend used in the coal/water slurry produced a distribution of 55% minus 200 mesh (74 microns). This represents particle sizes that are greater than usually used in pulverized coal combustion.

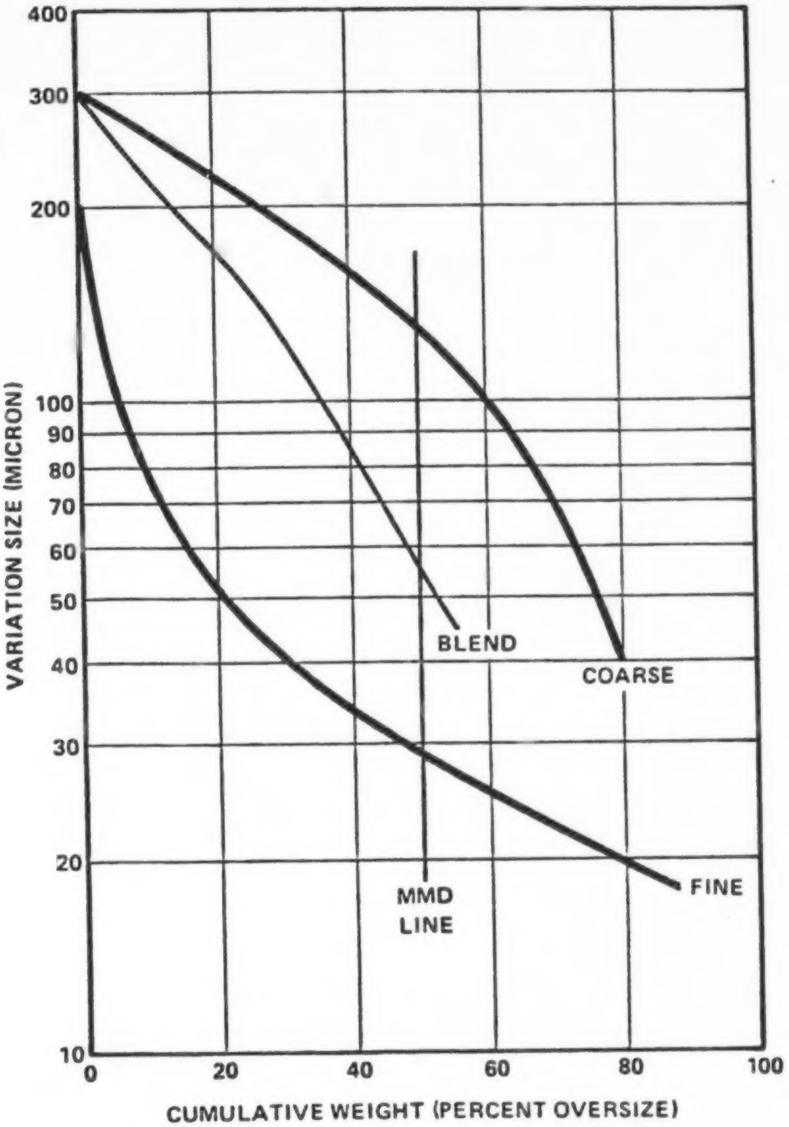


Figure 4. Particle Size Distribution of Pulverized Coal Used to Prepare Slurries.

IV. RESULTS

In any study of the present type there are innumerable parameters which affect the observed results. A listing of important independent variables would include the following:

Combustion and Furnace Parameters

- Air/fuel ratio
- Total fuel throughput rate (i.e., turndown or boiler rating)
- Secondary air temperature
- Secondary air inlet design (windbox)
- Fuel injector design
- Atomizing air (and/or steam) pressure
- Swirl air pressure
- Assist gas
- Refractory lining (diameter and length)

Slurry Parameters

- Loading
- Particle size
- Coal type
    - Heating value
    - Volatile matter
    - Ash

Some attention was given to each of these, at least in a qualitative or semi-quantitative way. It was learned at what settings or values of the above parameters fairly satisfactory combustion could be achieved. It was beyond the scope of the program to perform a complete evaluation of each of the independent variables. The main objective of the study was to determine under what conditions coal/water slurry could be burned, and toward that goal one baseline slurry was chosen and its performance evaluated by measuring combustion efficiency, the principal dependent variable, as a function of air-fuel ratio. Similar tests were also made with the COW slurry. It is worth considering briefly how combustion efficiency is determined.

COMBUSTION EFFICIENCY. There are two ways in which combusion efficiency can be obtained. One is by knowing the total throughput of all air and fuels and then measuring the carbon dioxide or oxygen content of the stack gas. This method can be illustrated best by a specific simplified

TECHNICAL PAPER
NO. 5

P-284

ADVANCES IN COMBUSTION TECHNOLOGY

(O_2 TRIM, CONDENSATION HEAT RECOVERY AND EMULSIFIED FUEL)

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4TH WORLD ENERGY ENGINEERING CONGRESS
ATLANTA, GEORGIA
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OIL/WATER EMULSIONS

For the past seven years, government and industrial researchers have investigated the use of emulsified residual fuel oil as a means to improve efficiency and reduce particulate emissions. It is fairly well established that the water, when properly disbursed in micron-size particles, causes the oil droplets to explode in a dramatic secondary atomization. On most burner/boiler combinations this secondary atomization is effective because the burners are not producing a sufficiently-fine oil spray. In those few cases, where a special effort was made to obtain high-quality atomization before using emulsions, emulsions have little initial effect on efficiency. However, over a six-month period the use of emulsion can result in maintaining a fairly uniform efficiency whereas the conventional burner performance may fall off a percent or two.

Another condition under which emulsified-fuel burning can pay off is at high turn-down conditions. Most burners fail to atomize well at low loads. The secondary atomization compensates for this condition and preserves a good efficiency at low loads. The decision to use emulsions or not could depend on the expected load variation for the boiler.

Secondary benefits of using emulsions are that the fireside of the boiler tubes remains cleaner and the viscosity of heavy residual fuel oil is reduced, often eliminating the need to heat the fuel. Also, the military has run tests which indicate that storable fuel oil emulsions are resistant to fuel tank fires or explosion.

This paper presents some descriptive information on the combustion process as well as a summary of available equipment. While emulsions may not be the answer for every boiler, the authors feel that they should at least be considered for every installation.

Combustion Phenomenon

The principal property of emulsified fuel combustion is a phenomena termed "micro-explosions" by those who first discovered it nearly 20 years ago. From results of a fundamental investigation on the combustion properties of single emulsified fuel droplets suspended from quartz filaments, Ivanov et al. (Reference 2 and 3), claimed that preferential, supercritical vaporization (i.e. micro-explosions) of the internal phase in a combusting spray of water-in-oil emulsion would be of sufficient violence to produce secondary atomization of the burning spray droplets. They reasoned that this property could be used to improve fuel atomization, decrease combustion time and reduce soot formation particularly for the combustion of residual fuels.

Ivanov summarized his findings by stating:

- Emulsified fuels burn faster than anhydrous ones.
- Water in emulsified fuels does not impair, but improves the combustion process, owning to the additional simultaneous breaking of the droplets, to the increase in evaporation surface of the droplets, and to a better mixing of the burning substances in air.
- The reduction of the combustion time of emulsified fuels has a favorable influence on the burning of sooty residue, thus improving the completeness of combustion and reducing the deposition of soot (seals) on the working surfaces.

Only within the last 10 years has the application of these principles to operational combustion systems been initiated. The potential importance of internal phase ratio, internal droplet size and distribution, were not investigated by Ivanov. However, recent experiments by Dryer (Reference 4) and others have confirmed earlier observations and suggest all of these variables must be considered if the process is to be optimized.

Free droplet studies by Dryer et al. (Reference 4 & 5), indicates gas phase soot inhibition at low water concentrations. The reason for this are complex. While gas phase soot formation occurs in the fuel vapor rich regions of diffusion (mixing) limited combustion, multicomponent heavy fuels also produce soot through liquid phase heterogeneous reactions. As the droplet burns, the lower boiling point compounds vaporize first, concentrating the heavier fuel components. Droplet temperature must increase with time in order to sustain vaporization, and surface temperatures are reached which are high enough to produce liquid-phase pyrolysis (coking). Even the recovery temperatures for distillate fuels may range high enough for these processes to occur, particularly if the fuel contains high boiler point aromatics or asphaltenes.

In operational combustion systems firing unemulsified residual fuels, similar droplet burning processes occur for arrays of droplets and lead to the formation of large carbon-containing particulates (>5 microns). These carbon particles may later be partially consumed through continued surface combustion.` Even if the better atomization achieved through micro-explosions only produced the same mass of coked material distributed as smaller particles, the increased surface area should lead to more rapid consumption of the soot through the surface combustion.

The minimum amount of excess air required in a boiler is generally defined by the limits on particulates or opacity, and this is where emulsions are of principal importance.

The combustion of a properly formulated emulsion can substantially reduce particulate formation. In many cases incipient particulate formation limits the amount of NO_x control which can be obtained through burner optimization, flue gas recirculation, combustion staging, or other techniques. Thus, as a complimentary control method, water-in-fuel emulsion combustion may be important to both thermal NO_x formation and fuel nitrogen conversion. Proper boiler tuning and emulsions used in tandem to mimimize excess air should have a pronounced effect on NO_x reduction as well as increasing efficiency. As discussed earlier in the paper, low excess air usually produces a high efficiency as well as low NO_x emissions. At low excess air conditions less NO_x is formed because less oxygen is available to react with atmospheric nitrogen to form the NO_x pollutant.

The direct addition of water to the combustion zone is also a means of NO_x control. However, for most boiler applications, this is not a practical use for emulsified fuel. The efficiency penalty is usually too high. Water addition reduces NO_x by lowering local combustion temperatures and reducing the chemical reaction of atmospheric nitrogen and oxygen. The effect is similar to that achieved by exhaust gas recirculation. However, water addition to the primary combustion zone must be at least of the order of 25% of the fuel in order to noticeably reduce thermal NO_x formation. These levels of water addition are undesirable in most applications since they result in an efficiency loss. A 50% NO_x reduction was reported by Combustion Engineering (CE) in a 150-MW tangentially fired boiler with a corresponding 5% reduction in efficiency at a water addition rate approximately equal to the fuel flow rate. The water in the experiment was added to the combustion air not by using a fuel emulsion which might be a more effective method. Even if the water flow was reduced by half, the efficiency loss would still be 2 to 3%. Therefore, most attention has been given to the use of emulsions to minimize excess O_2 which can be achieved in the rate of 5 to 10% water addition depending on the efficiency of the emulsifier and on the efficiency of the basic atomizer on the burner.

The degree of performance efficiency improvement due to the use of emulsified fuel depends to a large extent on the atomization achieved by the existing burning tip. In theory, if the burner can atomize the oil into small enough droplets, the water emulsion would have no benefit. The authors are aware of more than one instance where performance attained by water emulsions were equalled or exceeded by modification of the fuel atomization system.

A purely scientific evaluation of emulsion firing in a boiler has not been completed to date. Such an experiment is promised in a program sponsored by the U.S. Coast Guard. The program involves the long-term testing of a small, industrial size boiler (at the Coast Guard Academy in Groton, CT) first on regular residual oil and then on the same fuel emulsified in an optimized manner. Both runs will be for a 4 to 6 month period. Before both runs the boiler is to be properly tuned. The test boiler uses steam atomized burners which should insure good performance over the middle and upper load range. Furthermore, very careful performance measurements are planned which should produce valuable results.

Emulsor Hardware

For most effective O_2 reduction the water in the fuel oil droplets must be disbursed in a uniform particle size of from 1 to 10 μm. An emulsor which can distribute at least 90% of the water in this size range is considered effective. The emulsor should be equipped with an ability to vary the particle size within the above range to achieve the optimum performance.

In achieving the required water disbursion the emulsor should require minimum power, have high reliability, commercial availability and reasonable cost. Table 2 is a list of some available units and their principal of operation. Each was evaluated during the Coast Guard Program (Reference 6), and the Folland unit made by Folland Corporation of Quebec City, Canada, was selected.

TABLE 2. FUEL/EMULSOR MANUFACTURERS

Manufacturer	Location	Telephone No.
United Energy Inc.	Old Saybrook, CT	(203) 388-5377
Columbia Chase Corporation	Holbrook, MA	(617) 767-0542
Folland Enertec, Ltd.	Chambly, Quebec	(514) 658-8791
Elf	Paris Cedex 07, France	
Fuel Systems Design Corporation	Huntington Station, NY	(516) 427-2491
Gaulin Corporation	Everett, MA	(617) 387-9300
Fabcon, Inc.	San Francisco, CA	(415) 928-2400
Nahco System Corporation	New York, NY	(212) 594-6661

An installed emulsor for a 100 MMBtu/hr boiler will cost in the range of $35,000 to $50,000 (Reference 6). The mineral content of the water cannot be overlooked since it could cause a particulate problem. Since most emulsors have no moving parts, the only power requirement is for the fuel and water pumps. The operational costs are low.

As stated earlier, the decision to install an emulsor should be supported by a careful engineering analysis taking into acocunt the specific burner in the boiler, the load swings and the normal maintenance cycle. In certain cases, the emulsor can be cost-effective. It is recommended that an experienced combustion engineering firm be consulted in making such a decision because in the past many false claims and misleading interpretations have been given to this equipment.

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TECHNICAL PAPER
NO. 6

Emulsifiers increase boiler efficiency

Georgia-Pacific's installation of an emulsifier on a rebuilt package boiler has resulted in reduced fuel consumption, improved furnace cleanliness, and reduced particulate emissions.

Roger L. Nesbitt

A water and fuel oil emulsion consists of small droplets of water suspended in Bunker-C or No. 6 oil. Water is injected into the oil by an emulsifier, a device which generally uses resonators, ultrasonics, or mechanical cavitation to produce an emulsion. The size of the water droplets suspended in the oil usually varies from 5 to 20 microns, depending on the emulsifier utilized. At least one manufacturer claims to have the ability to control droplet size.

In theory and practice, approximately 5 to 10% water is added to oil to form an emulsion. After emulsification, the small oil-coated droplet of water leaves the oil burner tip and is exposed to the furnace flame. The droplet expands rapidly and vaporizes. When this occurs, the oil film coating the droplet ignites explosively. Based on limited flame observation, the overall effect is to produce a shorter, bushier flame which burns out quickly within the furnace envelope. Again, based on observations within the furnace, we suspect that the flame temperature is also higher than in the case of oil which has not been emulsified. The emulsification simply aids in atomizing oil at the burner tip. There is no reason to believe that this action would not be effective with either steam or mechanical atomizers. If improved atomization occurs, then it follows that air requirements can be reduced.

Installation

Georgia-Pacific Corp. recently installed an emulsifier on a 100,000 lb/hr (45,359 kg/hr) package boiler which had been rebuilt and retubed. The boiler generates steam at 400 lb (181 kg) pressure and 700°F (371°C) at full load. It has a pressurized furnace with observation ports at the two oil burners only. The boiler is a so-called "A" type boiler with all the superheater surface located in one boiler bank cavity on one side behind the furnace side wall. This means that the superheater receives less radiant effect than would the normal pendant superheater overhanging the furnace. The convection boiler bank is located in the other furnace cavity behind the opposite furnace side wall. Gas dampers are provided at the outlet of each boiler cavity pass and are arranged so that the flue gas can be balanced to allow for more or less flow through the superheater or boiler convection bank. The boiler is also equipped with a regenerative air heater. Since it is the smallest boiler in the plant and operates at low pressure and temperature, it can be shut down from time to time for internal inspection and observation.

Results

By testing and data collection, we have established the following:

1. Evaporation rate increased approximately 4 lbs (1.8 kg) steam per gal (3.8 liter) of oil burned, or 3% overall.

2. Soot blowing frequency has been reduced from once per 8 hr to once per 24 hr. Steam conservation from reduced soot blowing is estimated at 27,000 lb/day (12,247 kg/day).

3. Atomizing steam to oil burners has been reduced from a 20 psi (138 kPa) to a 10 psi (69 kPa) differential. Steam savings to the oil burners are estimated at 3,000 lb/day (1361 kg/day).

4. Both the reduced soot blowing and steam differential flow requirement appear as increased steam generation, and must be considered in evaluating the emulsifier.

Furnace cleanliness and its effect on boiler efficiency can only be measured long term by observation of fouling of the heating surfaces, draft loss change, and boiler performance. Assuming the water side of the boiler to be clean, and boiler setting conditions to be equal, then a measured decrease in efficiency or evaporation rate is accounted for primarily by heating surface fouling. If on the other hand, the emulsifier can

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Mr. Nesbitt is manager of Power and Recovery at Georgia-Pacific's Palatka, Fla. mill. This paper was presented at the 1980 TAPPI Engineering Conference.

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maintain the heating surfaces in a clean condition, then evaporation rate should remain constant over the long term.

On each occasion when the unit has been shut down for inspection, furnace side wall deposits have been light and relatively nonadherent. The bulk of the deposit can be swept or brushed away with a straw broom. Because of limited access and surface arrangement, superheater and boiler convection banks are difficult to observe visually. However, that portion which can be seen appears to be staying clean and bright. Thus far, there is no indication of deposit buildup anywhere within the setting.

The front wall or burner wall of the unit is not water cooled and is constructed of fire brick. The wall is clean and glazed and has no accumulation of oil ash or combustion products attached to it. The brick work is in good condition and does not appear to be deteriorating excessively.

Excess air usage, as indicated by a recording oxygen meter and a portable analyzer, has been reduced. Since the boiler is operated as a base load unit, careful setting of fuel-air ratio and emulsifier water to oil ratio produces an oxygen level at the boiler exit which can be reduced to between 1 and 1½%. Depending upon setting condition, the same reduction on an induced draft unit might not be possible.

With the emulsifier out of service and at full load, the unit is fan limited. With the emulsifier in service, fuel-air ratio is controlled. Conversely, at one-quarter load and with the emulsifier in service, the vanes of the forced draft fan are in minimum position and the furnace pressure is at zero inches of water, and further excess air trimming is not possible.

Operating fundamentals

If an emulsifier installation is to be successful, certain things are necessary. It is not possible, for example, to simply set the emulsifier in line and make any assumptions concerning results.

1. In the case of a unit which employs an optional flow meter to measure water flow, water quality is critical. It must be free of solids and have practically no color. G-P uses two strainers in series. The second or finer strainer must be cleaned on the average of once per week.

2. An oxygen analyzer-recorder is necessary if minimum excess air values are to be measured and controlled.

3. Accurate measurements of oil flow, water flow, and the percentage of water contained in the emulsion are certainly necessary. At minimum, excess air and water flow values appear to be critical. Dropping below the desired quantity will upset combustion conditions and produce smoke. Our (G-P's) unit incorporates a digital readout of each of the three variables.

4. Data must be collected and analyzed to determine optimum water requirements over the load range of the boiler. Our findings show that an emulsion with a higher percentage of water is necessary at lower loads than at higher loads. This is apparently affected by the range or turn-down ratio of the particular burners which we use.

5. The emulsifier must have the ability to adjust to changes in oil flow to the burner or steam flow from the boiler. We believe that it is critical to maintain the ratio of water to oil within close limits, if excess air optimization is to be achieved. It is equally important that fuel-air ratios be maintained within close tolerances. In terms of overall boiler efficiency, lowering excess air requirements appears to be the greatest advantage of emulsifier utilization.

6. Based on stack testing and base-load conditions with the emulsifier in service and operating with low excess air, particulate emission can be significantly reduced. In our case, the measured particulate has been reduced approximately 50% with the emulsifier in service.

CONVERSION OF THE 120 MW PAUL L. BARTOW PLANT UNIT 1 TO COM

Michael E. Higgins
Paul L. Bartow Plant
Florida Power Corporation

Florida Power Corporation is completing conversion of its Unit No. 1 of the Paul L. Bartow Plant to COM. This conversion is scheduled for completion in April 1982. The objective of the five year program is to demonstrate the commercial and technical feasibility of COM usage and to allow the transferring and utilization of this technology in other Florida Power Corporation facilities.

PRESENT UNIT CONFIGURATION

Unit No. 1 is a 900,000 lb/hr Babcock & Wilcox front-fired boiler operating at 1,800 psig throttle pressure and 1,000° F, both superheat and reheat. The unit was originally designed with 16 burners for use with oil, gas or coal. Only gas and oil capabilities were installed on the unit. Gas burning capability was removed from the unit in the early 1970s. The unit is a natural circulation, balanced draft configuration. The burners were modified in 1975 to a 12 burner operation. The units presently do not have any environmental clean-up for opacity or particulate. Florida Power elected to change out burners to a low excess air designed burner in order to meet the upgraded environmental standards. The unit was originally designed with 50° sloped bottom hopper, hoppers for the superheat, reheat and air preheater. The furnace was installed with a center division waterwall which was removed shortly after commercial operation. The unit was designed to handle an 8% ash coal at a net draft loss of 8.2 inches of water. Under present conditions of burning oil, the unit at times is temperature deficient. A fuel additive of magnesium oxide is used to slag up the walls to help maintain the superheat and reheat temperatures. The unit presently is induced draft fan limited. It is nominally a 120 MW unit and depending upon air heater pluggage, the unit is sometimes below that point. The air preheater is a Ljungstrom regenerative type with 48 inch baskets. The control system is the original Republic 40 volts AC type.

GENERAL DESIGN GUIDELINES

During the summer of 1980, Florida Power Corporation began the necessary engineering to convert the unit to COM. The basic design philosophy was to achieve a reliable unit which was capable of operating continuously on COM for five years. The unit is to meet all present environmental permit requirements. The design was to balance the cost of equipment against additional manpower for the five year period. Utilization of as much existing oil burning equipment from other sites was done to minimize cost and prove their adaptability to COM. In each of the individual areas, the risk was evaluated and equipment designed and purchased based upon the cost/benefits. As the design continued, there were two main points which were engineered to be assured of minimizing problems. The areas involved were the tankage and the particulate capture system.

FUEL DELIVERY SYSTEM

COM is to be delivered to the plant by barge and off-loaded to a modified 150,000 barrel storage tank. The tank has 4 vertical mixers supported by structures inside the tank installed for agitation and 3 nozzles installed for possible future recirculation. Mixers are of a angled paddle type design, consisting of 4 paddles with a diameter of 178". The speed of the agitators is established at 20 rpm. Mixers have electrical motors of 75 hp each. The purpose of the mixers being mounted vertically on the tank was to establish the maximum amount of mixing over the entire area of the tank. The mix system was designed to keep the tank mixed with two mixers as being a minimim requirement, three mixers as a maximum requirement, and a fourth mixer as a spare. Operational testing will resolve the actual required number of mixers. Once again, this is the area in which, if a problem did exist, it could possibly become insurmountable. The present testing which has been done on the type of COM mix that we will be using has presently shown that settlement may not be a serious problem. The suction heaters, burner pumps and burner heaters are located adjacent to the tank to minimize both the modifications inside the plant and possible suction head problems. The system is designed for 10,000 centipoise fuel at 130°F and a sheer rate of 1.5 sec $^{-1}$. The pumps are a Delaval twin screw type design modified to operate at 600 rpm via a belt drive with a discharge of 350 psig. The belt drive was selected due to 1) being able to change the speed if suction head problems became a concern, and 2) minimizing the actual cost of the installation as opposed to gearboxes. The pump system is designed with three (3) burner pumps; each pump is rated at 60% of full load capability. These pumps were used at our Crystal River site when that plant was on No. 6 oil. The pumps are to supply a constant supply of pressure to the combustion control valve with the burner pressure being varied from 20 to 150 psig. The fuel oil heater was also obtained from the Crystal River units and is between 100 - 200% oversized for the amount of COM which would be used on this unit. The heater is to obtain a rise in temperature from approximately 135 - 150°F to the 250 - 280°F operating temperature. The oil piping to the plant is insulated and heat traced to the burner front. The pumping system at the tank also has the capabilities to flush, burn or dilute the COM with No. 6 oil from an adjacent storage tank.[1] Flushing with No. 6 oil also will be used for the unloading arm line from the barge unloading to the tank. Quantity of recirculation from the burner front to the tank is being minimized to assure that the tank does not obtain elevated temperatures. Elevated temperatures on COM mixtures has shown to accelerate any settling effects of the coal.

BURNER SYSTEM

The new burner system is of the Peabody bullet head type steam atomized. Modifications to the head prior to startup are expected. These modifications will probably be to add hardened coatings or inserts to lengthen their life. New diffusers are to be installed but the burner throats are not to be modified at this time. Evaluations will be done to assess the need for possible modifications to a coal-type throat. Complete revamping of the valving system includes use of hydromotor valves from the original gang valve operation. The burner management system has been completely reworked to incorporate a microprocessor type unit. The safety interlock system has been reworked to meet the latest NFPA codes.

BOILER MODIFICATIONS

No pressure part modifications are being done on the boiler. Twenty-eight wall blowers are being installed for deslagging. The necessary bent tube sections for the wall blowers were existing in the original installation. The boiler hopper is being modified to accept the water impound hopper. The rear hoppers are being modified for ash removal of the superheat, reheat and air preheater areas.

ELECTROSTATIC PRECIPITATORS

The electrostatic precipitator is a 350 SCA design unit by GEESI (formerly Buell). It is of a divided box type design with no special features. The ESP control is of the intelligent microprocessor type utilizing two opacity monitors which will be averaged and integrated. The ESP was installed while the unit was on line with only a three week outage to rearrange flue gas ducting out of the way.

FLY ASH SYSTEM

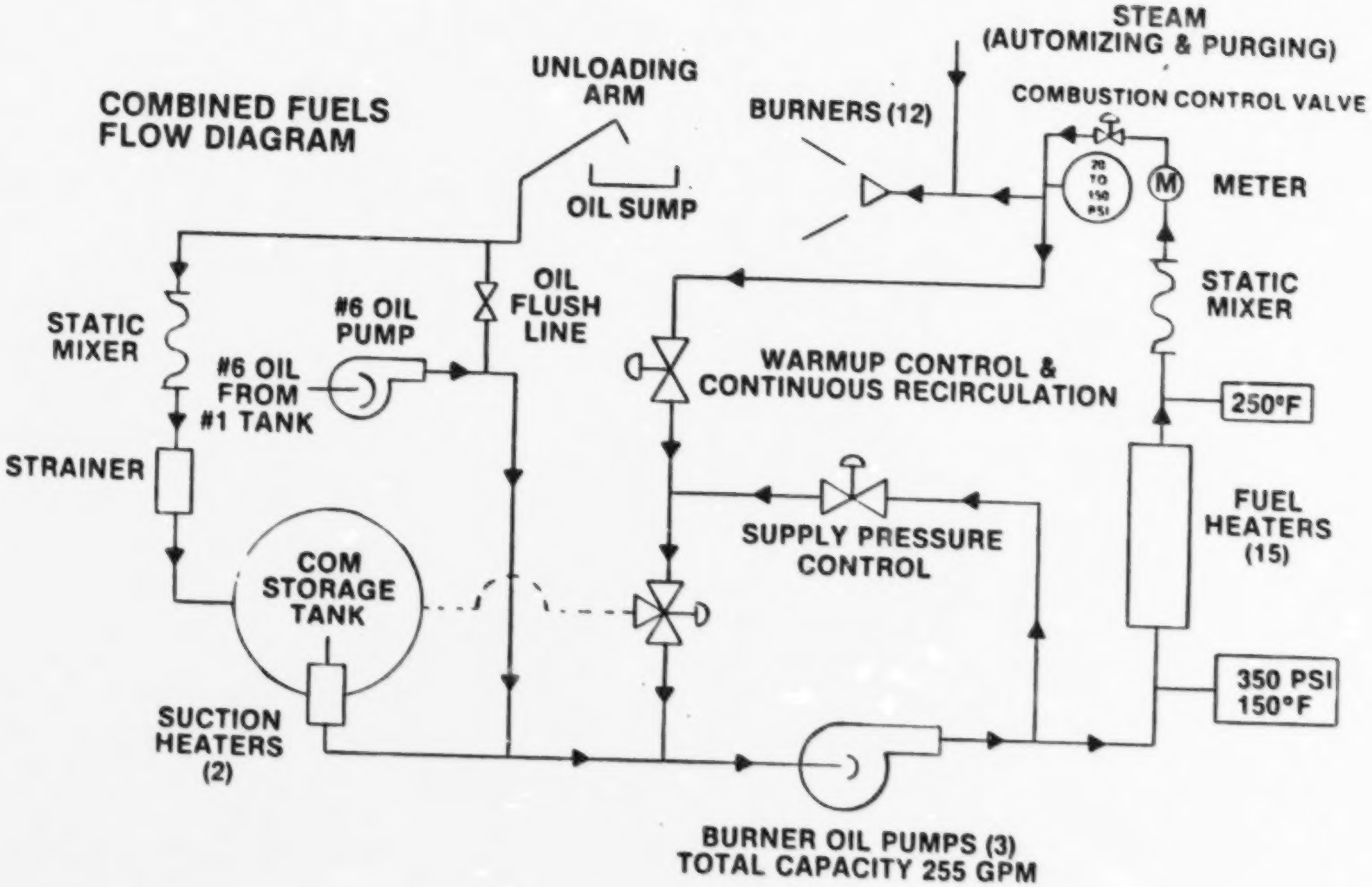
The fly ash system is of a dense phase type by Flakt. The system was selected due to its demonstrated capabilities for both oil and coal ash systems. It utilizes less air than the normal pneumatic system. This air is compressed and dried to a -40°F dewpoint. The system is designed to continuously remove the ash to prevent large build-up in any of the twelve ESP hoppers. When burning 100% oil, the ash will be removed in drums from the ESP area. When burning COM, the ash will be transported by a pipe to the impound area where it will be conditioned with water and stored.

BOTTOM ASH SYSTEM

The bottom ash system as selected is a submerged scrapper conveyor type design. It utilizes a drag chain with flight bars moving along the bottom of the hopper and pulls the ash up a dewatering slope. The ash is then dumped into a portable hopper which is transported to the impound area daily. The system was selected partially due to low water usage and elimination of the need for ash ponds. The system incorporates a water recirculation system consisting of pumps, a vacuum filter for removal of fines, a surge tank for level control, an air heat exchanger for cooling and chemical feed pumps for pH balancing.

TEST PROGRAM

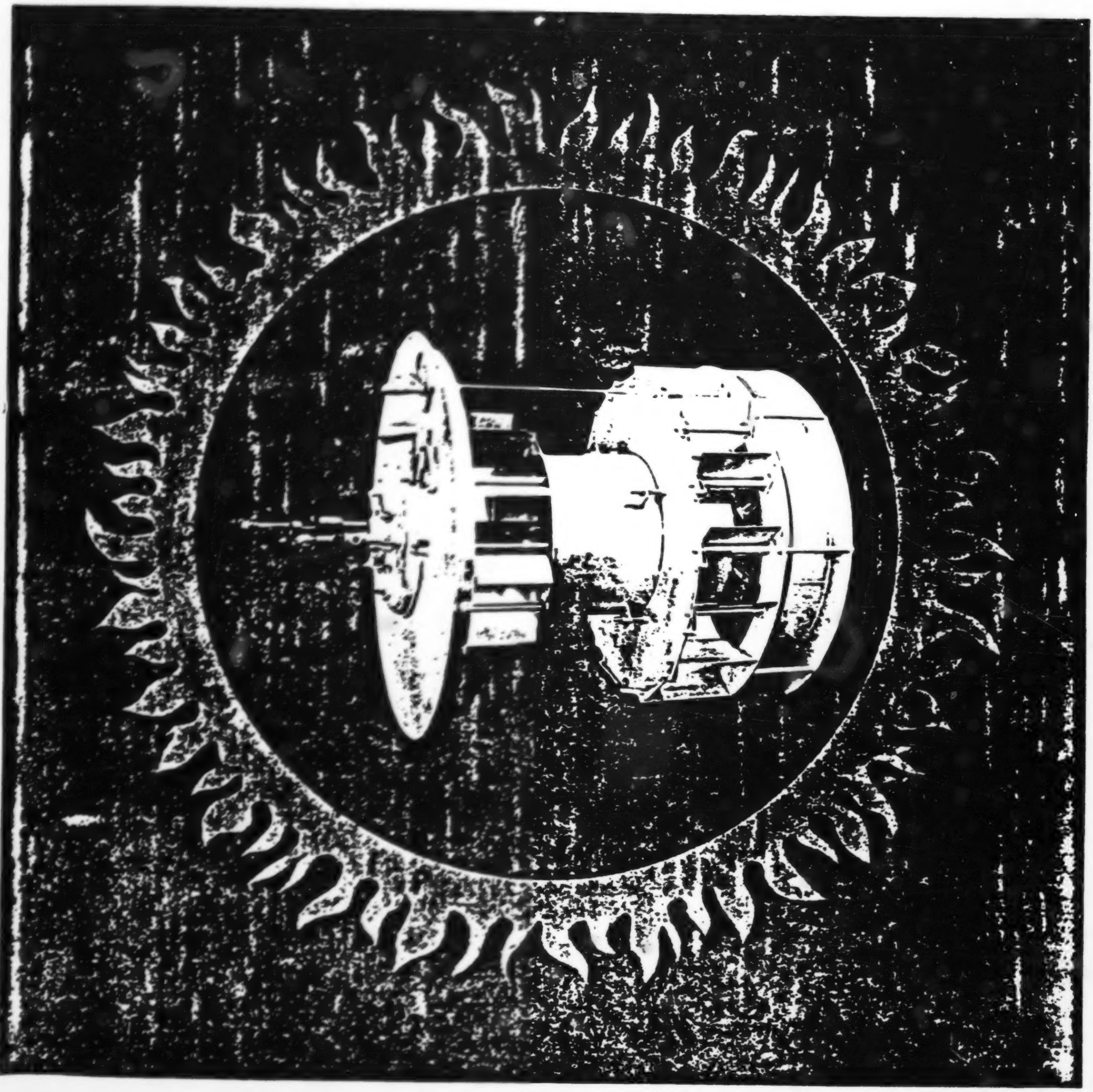
The testing program, as presently designed, is to answer the questions associated with continuous operation on COM with a special emphasis on those items where large capital dollars would be required. A task force has been formed to achieve the required testing. Utilization of manufacturer's testing capabilities are being incorporated with Florida Power Corporation personnel. The program has an intensive first year of testing with provisions for continuation as the need shows.


COMBINED FUELS FLOW DIAGRAM
UNLOADING ARM
OIL SUMP
STEAM (AUTOMIZING & PURGING)
BURNERS (12)
COMBUSTION CONTROL VALVE
20 TO 150 PSI
METER
STATIC MIXER
#6 OIL PUMP
OIL FLUSH LINE
STATIC MIXER
#6 OIL FROM #1 TANK
WARMUP CONTROL & CONTINUOUS RECIRCULATION
250°F
STRAINER
FUEL HEATERS (15)
SUPPLY PRESSURE CONTROL
COM STORAGE TANK
350 PSI 150°F
SUCTION HEATERS (2)
BURNER OIL PUMPS (3) TOTAL CAPACITY 255 GPM

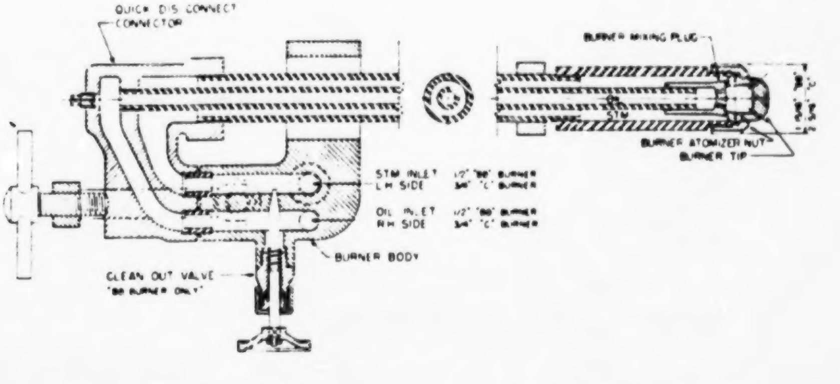
BULLETIN NO. 1

FABER

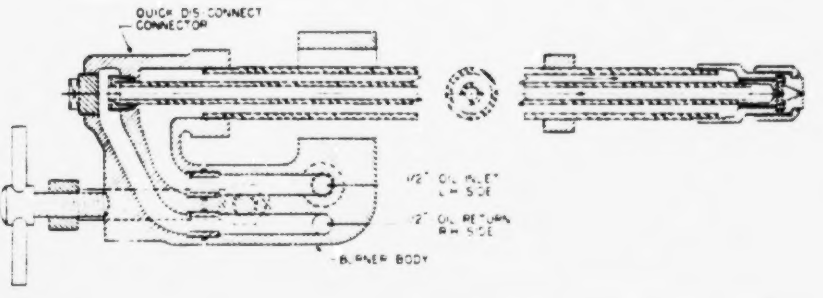
OIL — GAS — COMBINATION BURNER UNITS



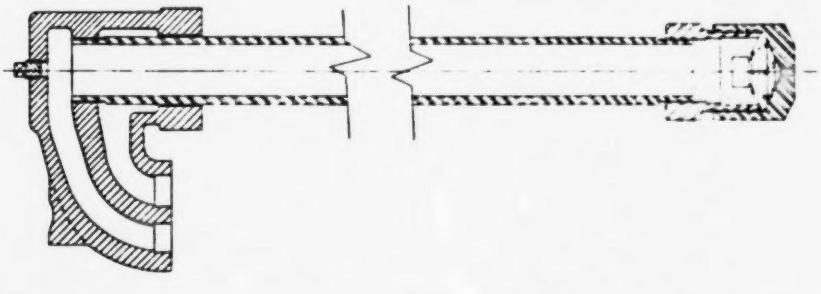
OIL BURNERS The prime function of the oil burner component is to convert liquid fuel in a finely atomized mist, which, when mixed with the turbulent air flow pattern, will result in a stable, efficient burning fuel. Faber oil burner units are designed and manufactured in such a manner that operators may quickly remove them from the register units, and provide for ease of disassembly for cleaning and inspection. All parts exposed to flame temperatures are of stainless steel and carefully machined for uniform capacity. The method of atomization of the fuel oil is by three basic types of units; that, depending on applications, each have their preference.


QUICK DIS CONNECT CONNECTOR
BURNER MIXING PLUG
STM
BURNER ATOMIZER NUT
BURNER TIP
STM INLET LH SIDE
1/2" "BB" BURNER
3/4" "C" BURNER
OIL INLET RH SIDE
1/2" "BB" BURNER
3/4" "C" BURNER
BURNER BODY
CLEAN OUT VALVE "BB BURNER ONLY"

STEAM ATOMIZING OIL BURNERS Faber steam atomizing oil burners are made in two sizes; type "BB" and type "C," and are similar in construction, differing only in size and capacity. Atomization of the finely divided oil streams is accomplished by steam impingement; resulting in a fine oil spray capable of wide capacity ranges of operation, at relatively low oil pressures. Steam for atomizing being less than one percent of boiler output. This type burner is especially adaptable to varying qualities of fuel oil, acid fuels, or sludge fuels, and capabilities of modulating over ranges of 10 to 1 turndown ratios on combustion controlled applications. Recommended viscosity for best atomization is 300 SSU.


QUICK DIS CONNECT CONNECTOR
1/2" OIL INLET LH SIDE
1/2" OIL RETURN RH SIDE
BURNER BODY

PRESSURE ATOMIZING, MECHANICAL RETURN FLOW OIL BURNER Faber type "MR" oil burners employ higher oil pressures, directed into tangential slots imparting a whirling motion to the fuel which, when released through the tip orifice, exits in a fine hollow cone mist. Inlet pressure to the burner is maintained at a constant pressure, and by varying the return oil flow volume through the back orifice, burner capacity is varied in modulation of 4 to 1 ratio. This type burner is employed in applications generally where steam is not available for atomization, and modest range of operation is required. Recommended viscosity for best atomization is 150 SSU.



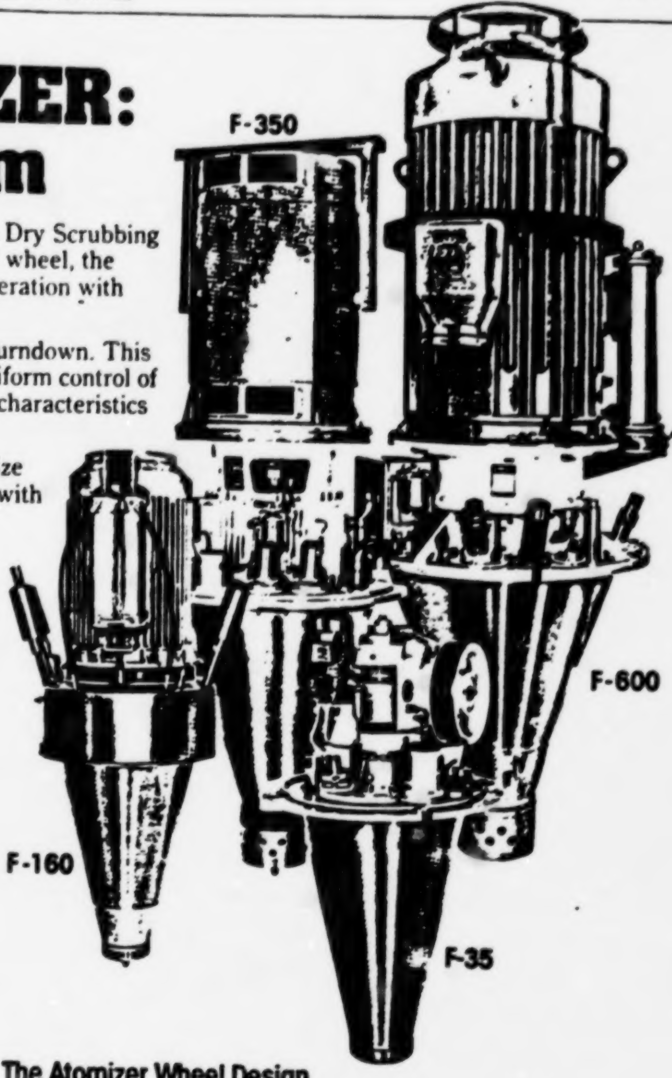
PRESSURE ATOMIZING MECHANICAL OIL BURNER Faber type "M" oil burners are the straight high oil pressure type that are used mainly for cold start up service, and have burner bodies interchangeable for operation with the steam atomizing or return flow oil burner units as described above. They are often used with light fuel oil requiring no preheating or heavier fuels with an electric oil heater to provide 150 SSU viscosity.

THE NIRO ATOMIZER: Heart of the System

The Niro Atomizer rotary atomizer is the heart of the SO_2 Dry Scrubbing System. With its unique, patented KN® abrasion-resistant wheel, the atomizer is designed for extremely reliable, continuous operation with minimum maintenance.

The atomizer is capable of virtually infinite reagent flow turndown. This feature, unique to rotary centrifugal atomizers, assures uniform control of water evaporation rates, SO_2 absorption, and end-product characteristics over a wide range of gas flow rates.

Niro Atomizer manufactures atomizers for many different size applications. Atomizers are in use for absorption systems with gas volumes of 20,000 ACFM to 2,000,000 ACFM.



Unique Design Features

The features unique to our SO_2 Dry Scrubbing Systems include the single rotary atomizer, the special atomizer wheel design, the two-point discharge system and the patented dry product Recycle Process.

The Single Rotary Atomizer

The design of the spray dryer absorber module is characterized by a single rotary atomizer in a single gas disperser system. The rotary atomizer is placed in the center axis of the absorption chamber and the gas to be treated is introduced symmetrically around the atomizer in a spiral or vortex-like flow from above the atomizer wheel. The symmetrical gas flow pattern principle, used in all Niro Atomizer industrial spray dryers, is essential for efficient, problem-free operation.

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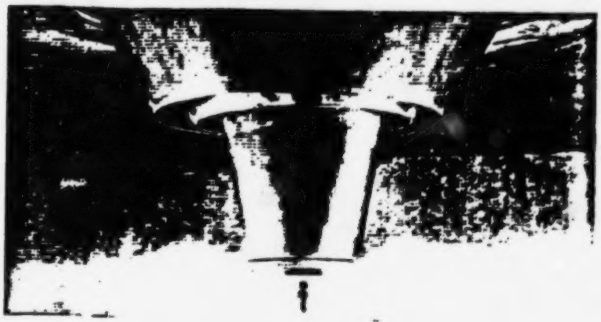


The single atomizer allows precise one-point control of the liquid flowrate, which is the most important controlled variable in any spray drying system. Uniform gas-liquid distribution and precise liquid flow control assure high SO_2 removal efficiency and a dry, free-flowing product.

Further info on how control is effected

The Atomizer Wheel Design

The Niro Atomizer type KN abrasion-resistant wheel consists of a machined stainless steel body with removable silicon carbide inserts in areas subject to wear. In highly-abrasive applications such as drying of mineral concentrates and kaolin, the KN wheel has proven itself trouble-free in more than twenty-five years of service.

The Two-Point Discharge System

In this design, a portion of dried spent chemicals and a lesser amount of the fly ash is collected from the chamber base discharge. Remaining spent chemicals and fly ash in the flue gases are recovered downstream in the particulate collector. The outlet duct exits horizontally from the side of the absorber chamber. This prevents plugged flues as it always provides an open passage through the spray dryer absorber system.

Recycle Process of Reagent

In our exclusive Recycle Process, unused reagent and a portion of the fly ash are recycled through the system. This offers substantial benefits in product drying and reagent handling.

Examples of products

Flotation concentrates:

- Chromium concentrate
- Copper concentrate
- Copper/nickel concentrate
- Copper/nickel/platinum concentrate
- Lead concentrate
- Manganese concentrate
- Molybdenum concentrate
- Nickel concentrate
- Pyrrhotite concentrate
- Tin concentrate
- Yellow cake
- Zinc concentrate

Chemical and electrolytic refining products:

- Ammonium molybdate
- Ammonium para-tungstate
- Basic nickel carbonate
- Cement copper
- Chromium residue
- Cobalt hydroxide
- Jarosite
- Nickel sulphate
- Precious metals slime
- Zinc leach residue

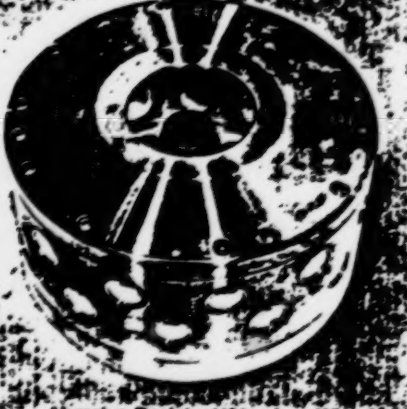
Others:

- Bentonite
- Calcium carbonate
- Cryolite
- Diatomaceous earth
- Kaolin
- Red mud
- Rock phosphate
- Steel making fumes

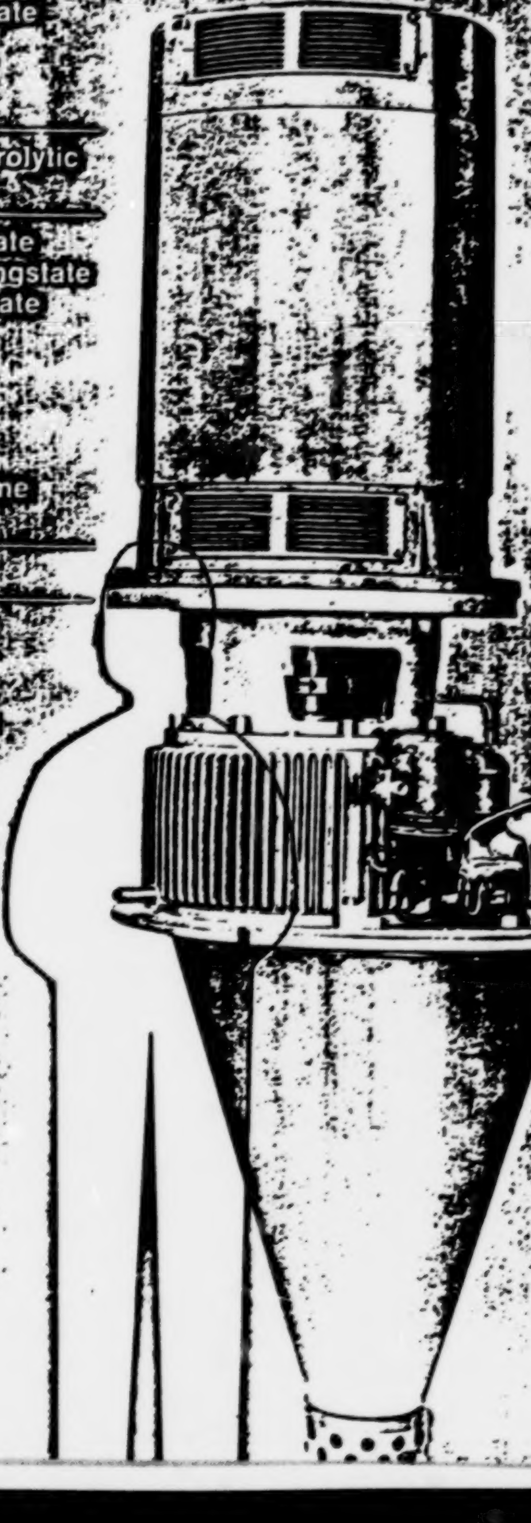
The rotary atomizer wheel as shown on the photo is a patented design that has been proven through years of continuous operation to withstand the abrasion and corrosion of mineral concentrates. The atomizer wheel is equipped with wear-resistant sintered bushings so arranged that a protective layer of concentrate builds up in the inner wheel chamber.

The mineral concentrate in fact provides its own protective layer – the most efficient abrasion control possible. A wear resistant base plate protects the lower wheel body. The bushings can be turned 90 degrees at a time, thus quadrupling bushing life. The wheel body is fabricated of special chrome nickel alloy steels.

BULLETIN NO. 2.1



Abrasive Resistant Atomizer Wheel. Sizes available handling up to 200 MTPH Concentrate Feed.

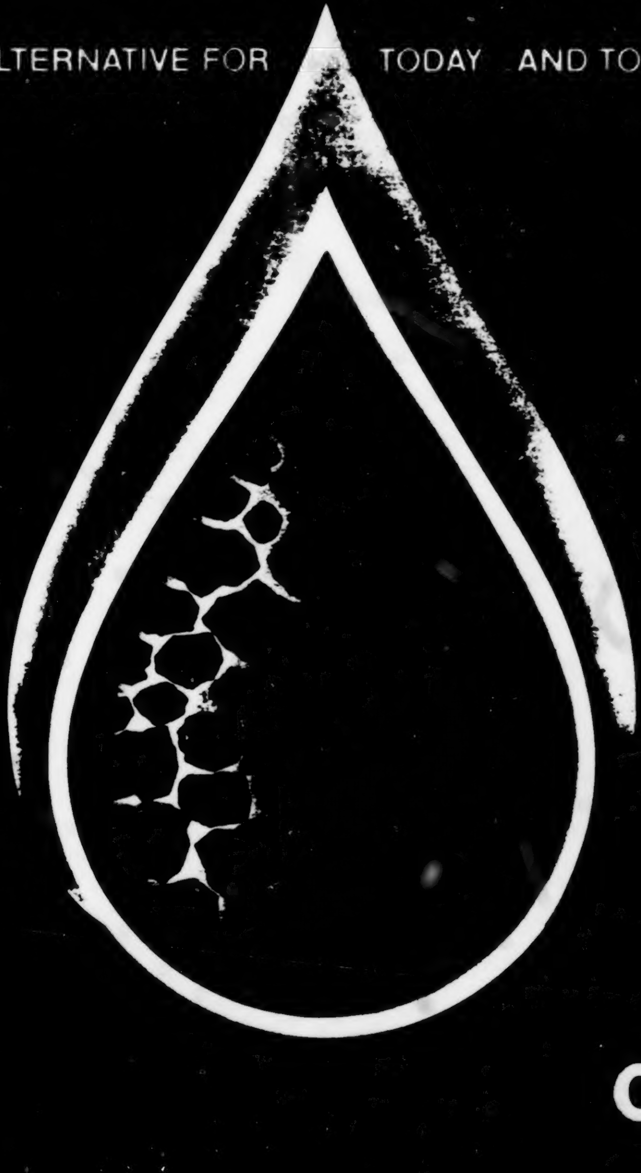


Typical Niro Atomizer High Tonnage Rotary Atomizer Unit.

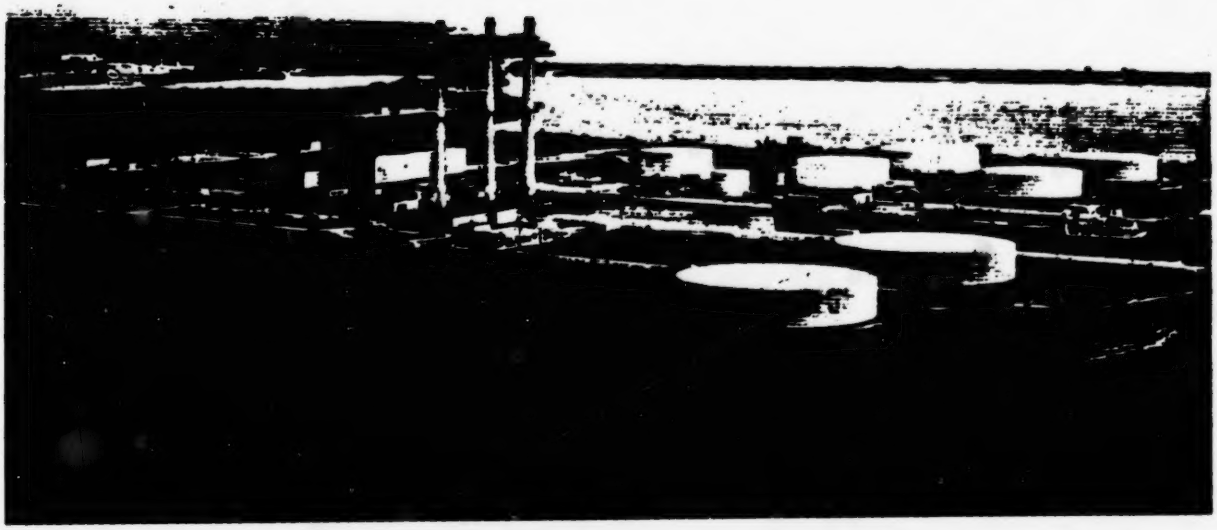
BULLETIN No. 3

COMPOSITE FUELS

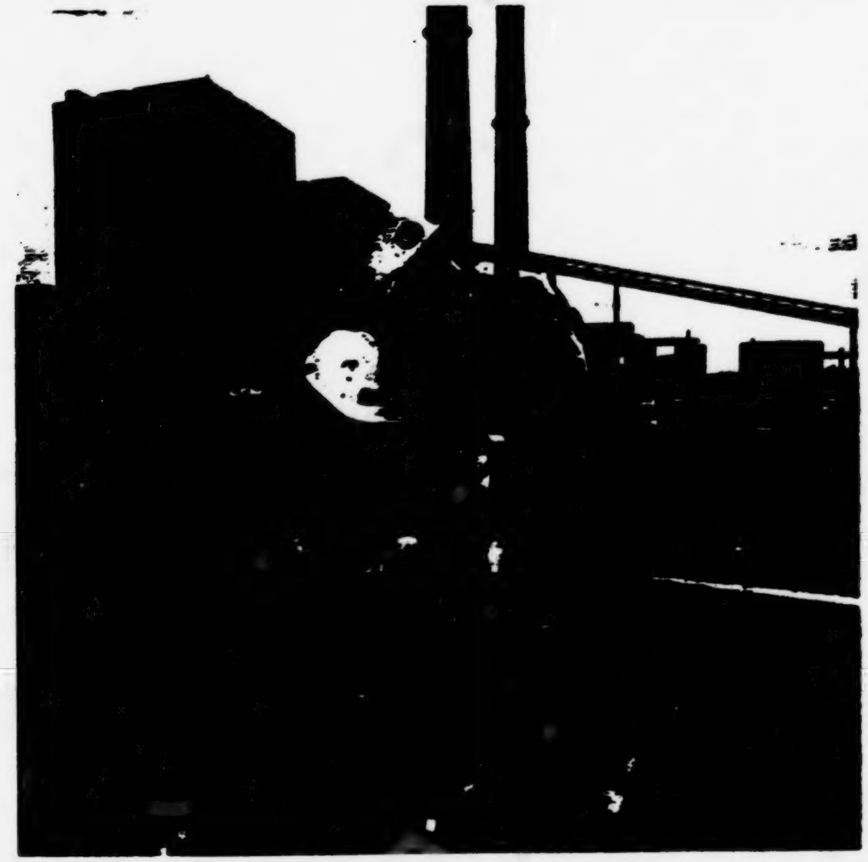
THE ENERGY ALTERNATIVE FOR TODAY AND TOMORROW



COMCO



Above—The 125-Mw Unit #1 of Bartow Station, the first utility boiler to be converted for permanent COM use.



Right—Crystal River Generating Station's Unit #1, the site of the initial firing of COM in a utility boiler.

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COMCO

COMCO...AN INTRODUCTION

A joint venture company formed in 1978, COMCO specializes in composite fuels, one of today's most promising energy alternatives for electric utilities and industry.

COMCO's primary business is the sale of coal-oil mixtures and other composite fuels or processing services from its own regional preparation plants or from smaller facilities at customer plant sites. COMCO will supply fuel on a contract basis to meet user specifications. Such contracts may range from spot purchases to long-term commitments and include the option of using customer-furnished fuel components. In particular situations, COMCO will also consider selling fuel preparation plants and related technology.

In support of its basic fuel sales function, COMCO can assist fuel users or their consulting engineers in the evaluation of specific projects for conversion to composite fuels. Such evaluations could entail technical and economic feasibility studies, fuel specification development and laboratory characterization. COMCO can provide a wide range of test and demonstration fuels. The organization also has the technical base to handle other customer requirements related to fuel conversion including transportation, storage, handling and combustion.

THE COMCO ORGANIZATION

COMCO combines the skills and experience of three diverse organizations—a leading engineer constructor, a large electric utility and a major energy supplier—to spearhead the development and commercialization of various composite fuels. These organizations include:

Dravo Corporation...

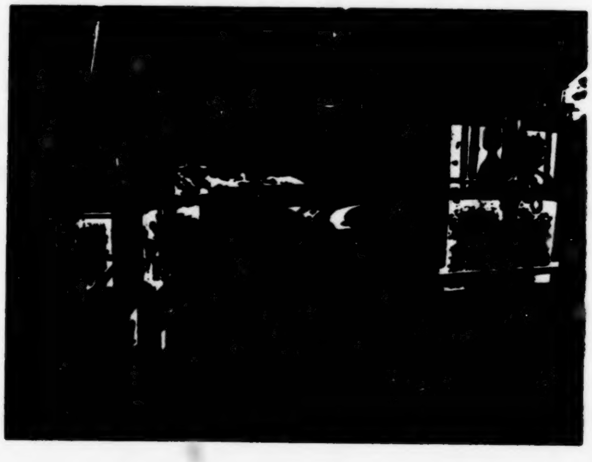
A major, worldwide engineer constructor with experience in process facilities for minerals and metals, coal, chemicals, synthetic fuels and pulp and paper, as well as electric power plants and transmission systems. The diversified firm is also well versed in bulk materials handling and pollution control technology, is a major producer of lime and aggregates, is involved in several heavy fabrication operations and operates a large barge line.

Florida Power Corporation...

An investor-owned electric utility serving central and western Florida. The company has over 5,000 megawatts of fossil and nuclear-fueled generating capacity. Integrated coal procurement activities include mining, rail and water transportation, and terminaling. It was the first utility to conduct a major test of a coal-oil mixture and to implement a permanent unit conversion.

A.T. Massey Coal Company, Inc....

One of the largest coal producers in the United States. Long a supplier to major domestic and overseas utilities and industrial customers, it is expanding facilities to double 1980 sales of 22 million tons. The firm controls a billion tons of low-sulfur Appalachian coal reserves and is acquiring additional reserves. It also operates large coal preparation plants and inland and coastal coal terminals. Its owners are St. Joe Minerals Corporation and the Royal Dutch/Shell group.



COMPOSITE FUELS

Composite fuels are a combustible mixture of one or more solids with one or more liquid carriers. These hybrid fuels can be made from such components as:

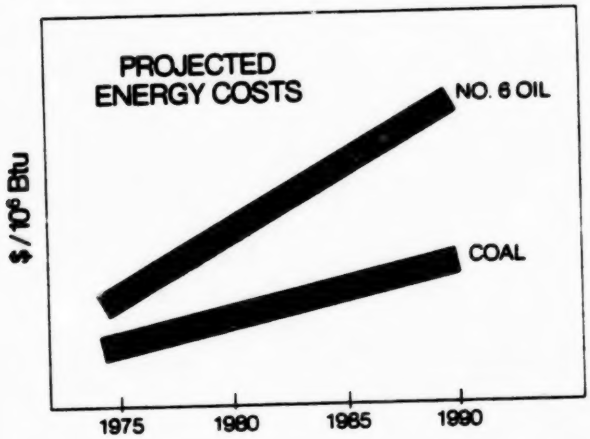
SOLIDS	LIQUIDS
Bituminous coal	Oil
Anthracite coal	Synfuel
Petroleum coke	Water

Applications

Composite fuels can replace fuel oil in such applications as utility boilers, industrial boilers, marine boilers, dryers, kilns and furnaces.

Current Status

One major type of composite fuel, coal-oil mixtures, has been tested extensively and is being applied on a commercial basis. Continued work on fine coal beneficiation, aimed at greatly reducing ash and sulfur content, promises to make coal-based composite fuels a highly acceptable substitute for fuel oil. Ongoing work to substitute lower-cost liquid carriers for oil should make composite fuels even more attractive economically.

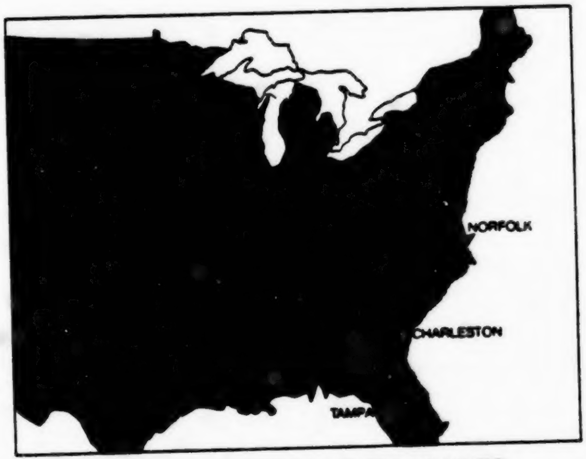


Advantages

Composite fuels combine the handling benefits of liquid fuels with the cost advantages of solids to provide the most economical substitute for fuel oil in many applications. Savings result from lower fuel costs and greatly reduced capital investments for fuel conversion. These hybrid fuels offer near-term insurance against oil supply interruptions and, in the longer term, should help fill the gap caused by the use of an increasingly greater percentage of scarce crude oil for gasoline and other higher-priced refinery products.

Availability

Composite fuels can be supplied from dedicated, on-site facilities or can be delivered by truck, rail, barge, tanker or pipeline from high-capacity regional preparation plants. COMCO will build regional facilities at strategic locations such as those shown for the southern and eastern portions of the United States.



REGIONAL PREPARATION PLANTS

COAL-OIL MIXTURES

Selection of Feedstocks

Most types of coal and fuel oil can be used as feedstocks for coal-oil mixtures (COM). However, final selection for a particular application is governed by fuel economics, environmental regulations, ash fouling or contamination considerations, and specific equipment limitations.

Preparation Technology

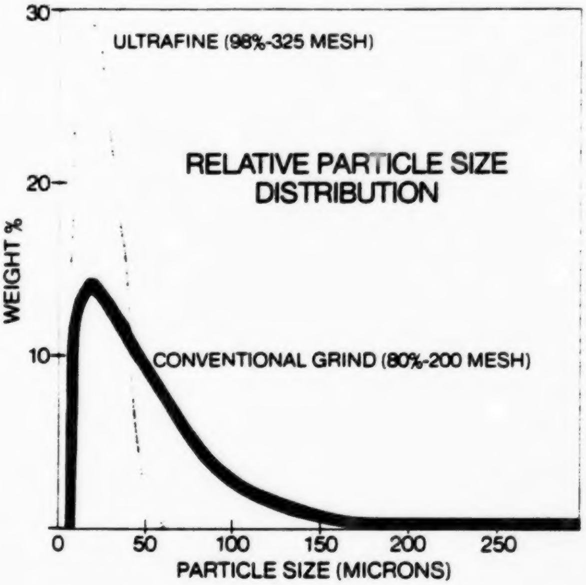
Technical approaches to preparing COM fuels focus primarily on stabilizing the mixture. Coal pulverized to conventional commercial size, 80% passing 200 mesh (.074 mm), readily settles out of fuel oil, including No. 6 oil. COM fuels utilizing conventional pulverized coal must be stabilized by continuous agitation or costly chemical additives. An alternative approach pioneered by COMCO involves ultrafine grinding techniques which reduce coal to 98% passing 325 mesh (.044 mm) size. Cost competitive, this method results in a stable mixture while reducing the potential for fuel system erosion.

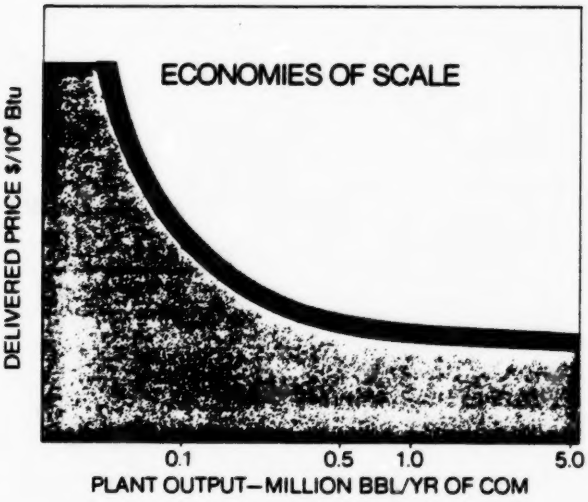
Supply Economics

Economics favor the highest possible coal loading in COM fuels, but mixture viscosity limits most such fuels to 50% coal by weight (40% Btu content). Preparation of the mixture at a user site is usually economically viable when large amounts are required and existing coal and/or oil handling facilities can be used. Frequently, however, a large, efficient, strategically located regional plant offers more attractive fuel economics. As a general rule, COM fuels can be delivered on an extended basis from a facility producing at least 500,000 barrels per year at appreciably less cost per Btu than No. 6 oil.

TYPICAL FUEL PROPERTIES

	COAL	NO. 6 OIL	COM
Btu/lb.	12,000	18,200	15,100
Btu/bbl. ($x10^6$)......		6.2	6.0





USER CONSIDERATIONS

Economic Perspective

Conversion to COM fuels requires the user to consider the economic trade-off between projected annual fuel savings and the capital investment required to make the conversion, including incremental operation and maintenance costs. Factors such as the remaining life of the fuel-burning facility and the cost, availability or alternative use of scarce capital are also important.

Storage and Handling

Residual fuel oil transportation and handling equipment can be modified for COM fuels while retaining the ability to serve its original purpose. COM fuels can be stored in conventional tanks properly equipped with heating coils and recirculation equipment.

Combustion

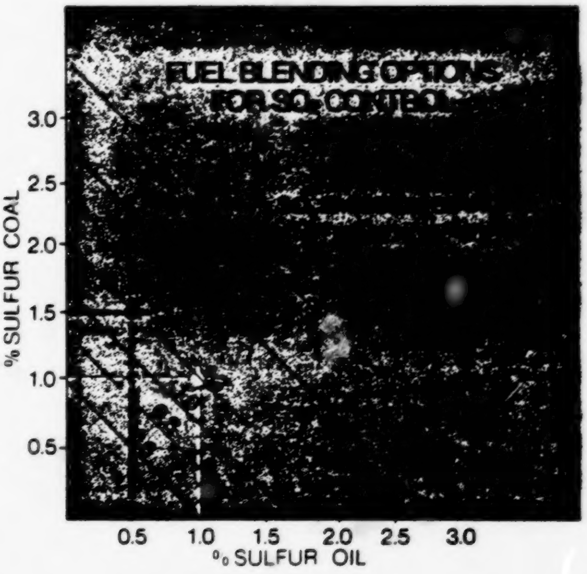
Burner system modifications depend on specific circumstances. Often the existing system can be upgraded to accommodate dual fuel use. Soot blowing capabilities are necessary to eliminate boiler ash buildup and slagging. Boiler derating is dependent upon unit design. Generally, boilers designed for coal firing require minimal to no derating. Derating in equipment designed strictly for oil firing is greater and is strictly dependent on specific equipment design. Often, derating may be acceptable for base load since peak demand can be met by temporarily decreasing the coal content of the COM fuel.

Ash Handling and Control

Boiler bottom and fly ash handling and disposal systems are required for firing COM fuels. In a majority of cases the required system is simpler and less expensive than a conventional design and full coal firing. Nonboiler, industrial process applications of COM fuels may require consideration of possible fuel ash contamination of processed materials.

Environmental Regulations

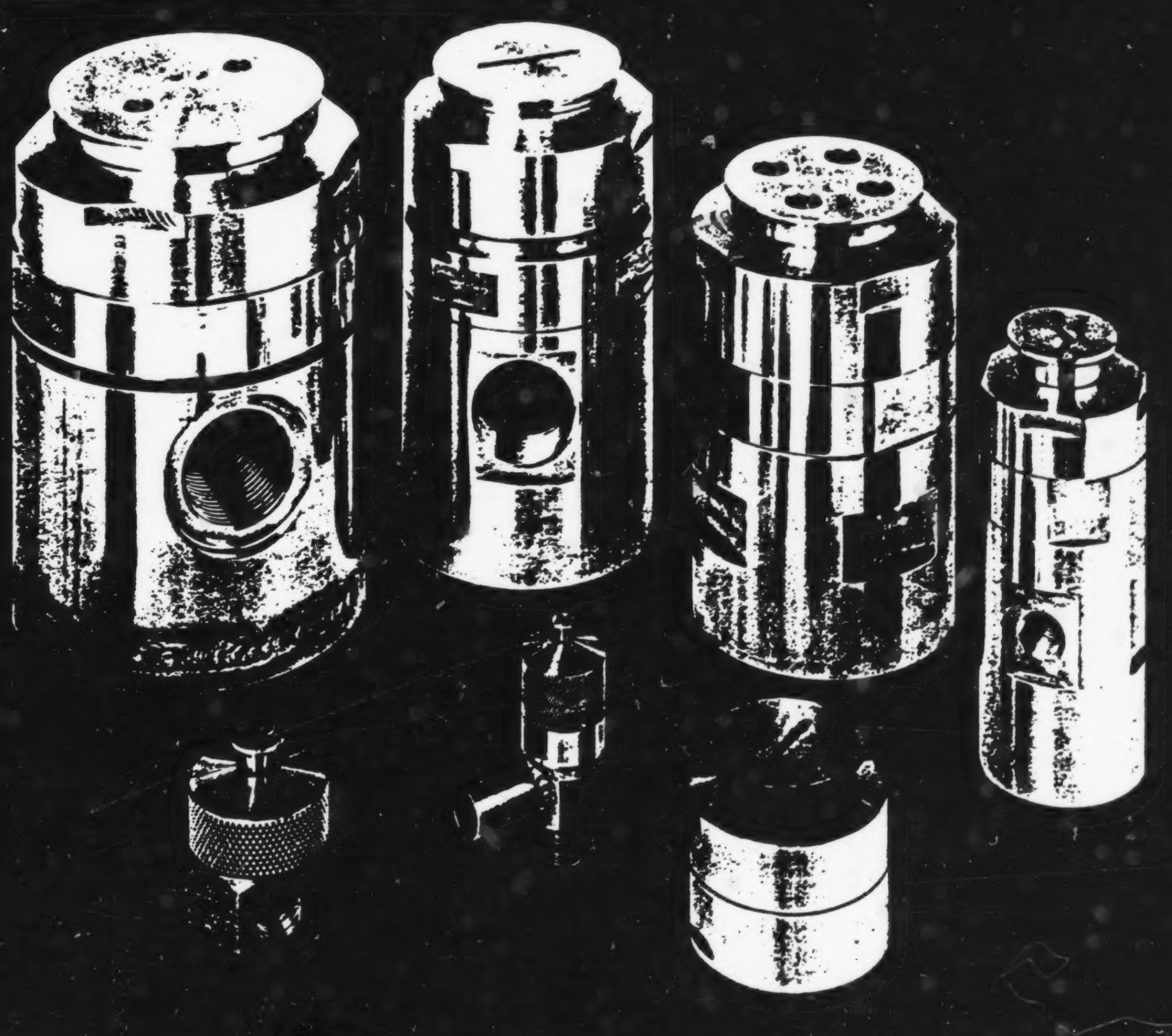
Conventional electrostatic precipitators or bag filters are needed for particulate control. Sulfur emissions can be reduced by proper selection of coal and/or oil feedstocks. Environmental regulatory agencies have generally been responsive to COM fuels use, and conversion does not necessarily mean that Federal NSPS standards will be applied.



FLOSONIC®

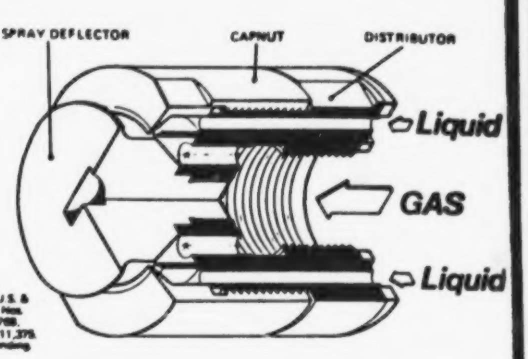
SUPERSONIC ATOMIZERS

BULLETIN NO. 4



Fluid Kinetics Inc.

FLOSONIC® ATOMIZERS FROM FKI



Licensed under U.S. &
Canadian Patent Nos.
3,741,484, 951,788,
3,923,248 & 1,011,375
Other Patents Pending

OPERATING PRINCIPLE

An exploded view of the atomizer is shown above. It consists of three components, Spray deflector, Capnut and Distributor.

Compressed air is delivered to a chamber formed by the spray deflector and distributor. The outlet from this chamber is an accurately sized concentric annular nozzle. The air flows from this nozzle at sonic velocity underneath the exit from the outer annular liquid chamber formed by the capnut and distributor.

The liquid film is accelerated by the air and is reduced and sheared.

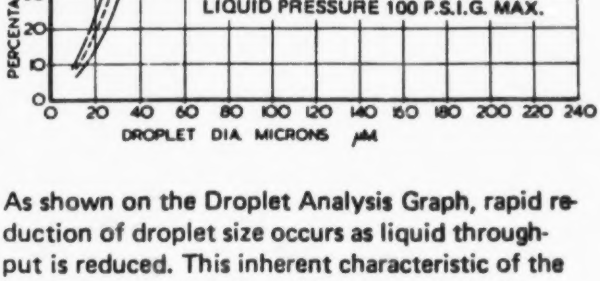
The compressed air expands during this stage and forces the liquid away from the surface of the spray deflector forming an effective divergent nozzle between the spray deflector and liquid film. Supersonic velocities are attained culminating in violent pressure fluctuations. Shock waves vibrate the liquid layer causing further shearing, and break-up occurs in a plane perpendicular to the horizontal shearing. Atomization is complete and the spray diverges at an angle determined by the final diameter of the spray deflector.

The air cushion between the spray and the spray deflector prevents re-entrainment of droplets and wetted metallic surfaces

Small orfices required in high pressure nozzles are prone to clogging, rapid wear and, in general, have a small turn-down ratio envelope within which satisfactory atomization can be developed.

In contrast, FloSonic® atomizers incorporate a 360° annulus liquid discharge, require low liquid pressure, have large liquid ports and clearances, and provide a wide turn-down envelope.

Sonic Wave Atomization Droplet Analysis



As shown on the Droplet Analysis Graph, rapid reduction of droplet size occurs as liquid throughput is reduced. This inherent characteristic of the atomizer permits full modulation of liquid flow which is especially important for gas cooling and other evaporative dependent processes.

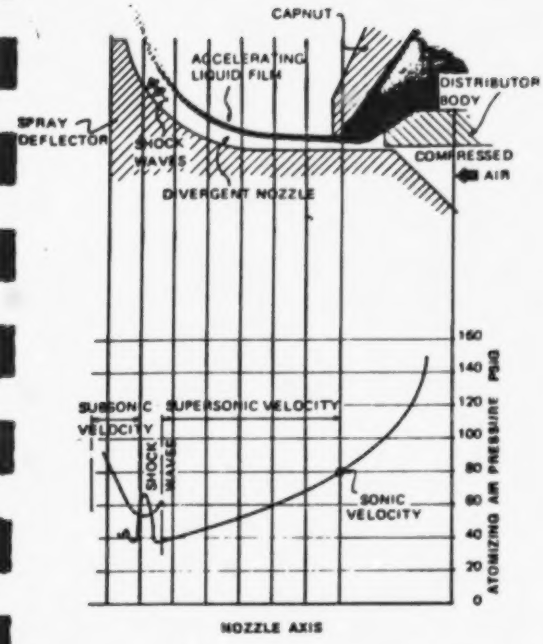
COMPRESSED AIR REQUIREMENTS

Compressed air from reciprocating machinery is expensive per unit volume but is relatively inexpensive for low volumes and high pressures. For this reason the Sonic Wave Atomizer was designed to operate with an air mass-pressure ratio of 0.03 and it is possible to atomize 960 GPH of water using only 40 SCFM of air at a pressure of 100 PSIG; a power-water ratio slightly better than 0.01 HP/GPH.

HOT WATER/AIR TECHNIQUE

Water, like most other liquids, is temperature sensitive. A Viscosity Chart shows that water at 176°F. requires only 1/3rd the power required to shear water at 68°F., i.e. 0.0036 and 0.01 poise respectively.

Tests show that this atomizer, spraying water at 158°F., provides a predictably improved performance in accordance with the lower viscosity. Of equal importance for gas cooling, each droplet contains up to 80% of its sensible heat. Since the droplets need absorb only 20% more of the heat required to bring them to the boiling point, flash-off time is still further reduced.


CAPNUT
ACCELERATING LIQUID FILM
DISTRIBUTOR BODY
SPRAY DEFLECTOR
SHOCK WAVES
COMPRESSED AIR
DIVERGENT NOZZLE
SUBSONIC VELOCITY
SUPERSONIC VELOCITY
SHOCK WAVE
SONIC VELOCITY
ATOMIZING AIR PRESSURE PSIG
160
140
120
100
80
60
40
20
0
NOZZLE AXIS

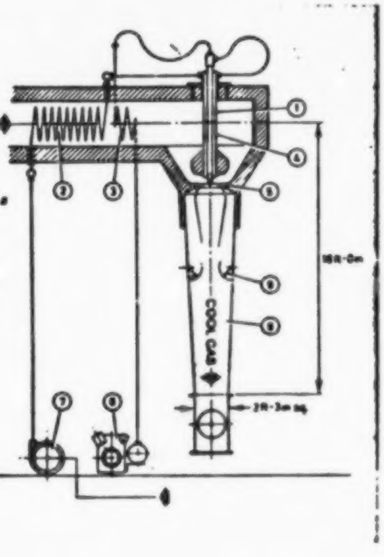
hich invariably give rise to a small but troublesome percentage large droplets.

e plot of air pressure vs. nozzle axis is a simplified representa- f the actual expansion process.

Similarly, if the atomizing air is preheated to 400°F., for example, the compressed air usage is reduced by approximately 25 per cent. Atomization is further improved since the sonic velocity of the air in the nozzle throat is increased by approximately 20 per cent.

Diagrammatic arrangement of a cooling system:

1. Sonic wave atomizer lance
2. Water heating coil
3. Compressed air heating coil
4. Water heating jacket
5. Refractory mixing orifice
6. Air compressor
7. Water pump
8. Evaporation duct
9. Trimming dampers


HOT GAS
COOL GAS
16ft-0in
2ft-3in sq.
1
2
3
4
5
6
7
8
9

STANDARD* DX SERIES – 6 to 2400 G.P.H.

Model No.	Maximum Flow Rate		Air Consumption at 100 P.S.I.G.	
	G.P.H.†	Liters/Min	S.C.F.M. ††	Liters Min
DX 00	48	3 1	2 5	70
DX 0	202	12 7	8	226
DX 1	384	24	13	368
DX 2	516	33	18	510
DX 3	672	42	26	737
DX 4	960	61	40	1130
DX 20	1500	95	70	1980
DX 30	2400	152	100	2830

+Max. Liquid PSI – 100 PSIG

++To convert for steam, multiply by 2.4 to obtain saturated steam at 100 PSIG

STANDARD* MS SERIES – 1 to 360 G.P.H.

- For ultra-fine spray applications. Maximum liquid flow rates are 15% of DX Series. Change DX prefix to MS. (See Droplet Analysis Chart on Page 2.)

MATERIAL OF CONSTRUCTION

- All DX and MS Series atomizers are 316 S.S. as standard. Atomizers can be fabricated from any machineable material widening their application to include most corrosive liquids.
- Deflectors and other nozzle parts are also available in wear resistant materials e.g. silicon nitride, carbide ceramic, and aluminum oxide ceramic for handling abrasive liquids or slurries.

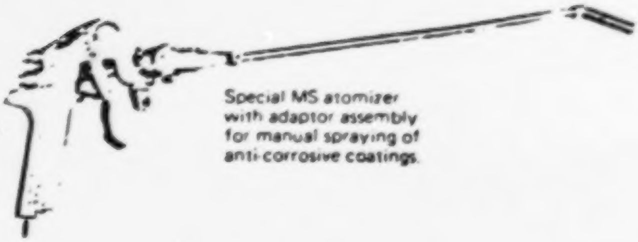
COMBUSTION APPLICATIONS

- Deflectors are provided with a patented anti-carbon air bleed on the front surface of the atomizer.
- CL Series atomizers for coal liquid fuels and other abrasive slurries. Request CL Series bulletin.
- ML Series atomizers for external mixing and combustion of a waste by-product with a primary petroleum fuel. Request ML Series bulletin.

MOUNTING ADAPTORS AND ACCESSORIES

- Except for MS-00 and DX-00 models, all atomizers require mating adaptors onto which the nozzles are threaded.
- Standard adaptors provide air and liquid pipe ports which connect to supply lines. Socket weld adaptors are also available for fabrication of concentric tube lance assemblies.
- FKI will also design and furnish complete lance assemblies, special adaptors and unique configurations to handle most installation requirements.

*Non-standard sizes available to order.



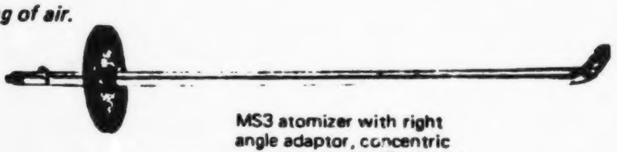
Special MS atomizer
with adaptor assembly
for manual spraying of
anti-corrosive coatings.

Special high volume
14000 G.P.H. atomizer.

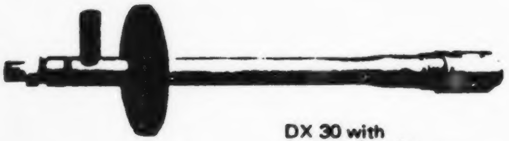
MS20 360° flat spray
atomizer mounted on
pipe adaptor.

APPLICATIONS INCLUDE

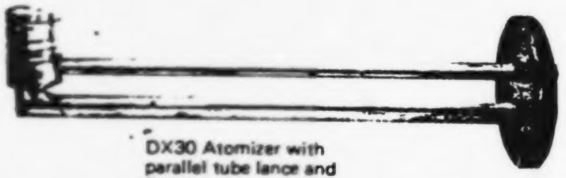
Hot Gas Cooling and Conditioning.
Municipal Incineration.
Humidification and Conditioning of air.
Spray Cooling.
Oil Fogging.
Gas Scrubbing.
Dust Suppression.
Insecticide Fogging.
Ultra Low Volume Spraying.
Edible Fat Spraying.
Blending Processes.
Perfume Spraying.
Acid Spraying.
Fuel Oil Combustion.
Coal Liquid Mixture Combustion.
Carbon Black Processing.
Dry and Wettable Powder Dispersion.
Paint Spraying.



MS3 atomizer with right
angle adaptor, concentric
tube lance, and ASA flange.

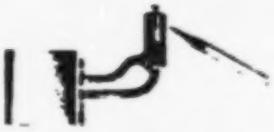


DX 30 with
concentric tube
lance and ASA flange.



DX30 Atomizer with
parallel tube lance and
flange.

ML3 Dual Liquid Nozzle
for simultaneous mixing
and combustion of No. 6
fuel oil and waste product.



Special atomizer for
ultra-low flow.

WITH YOUR INQUIRY PLEASE INCLUDE THE FOLLOWING INFORMATION

1. General purpose for which atomizer is to be used.
2. Type of liquid to be atomized.
3. Quantity of liquid to be atomized.
4. Maximum permissable droplet size.
5. Chemical properties of liquid including viscosity and temperature relationship.
6. Type and size of solid contamination in liquid.
7. Liquid pressure.
8. Pressure and quantity of atomizing gas pressure, if available.
9. Type of environment in which atomizer must operate.
10. Any other relevant information, e.g. duct arrangements and mounting requirements.

REPRESENTED BY.

Fluid Kinetics Inc.
4859 Factory Drive, Fairfield, Ohio 45014
Tel. 513–863-6667 • TWX No. 810–461-2347

North American
Mfg Co
Cleveland, OH 44105 USA

FULL EMULSION OIL ATOMIZERS

BULLETIN **56.42**
8-82

Series 5642 Full Emulsion Atomizers atomize liquid fuels with high pressure steam or compressed air and are particularly suitable for high temperature, continuous duty applications.

Matched sets of oil, steam, and emulsion orifices permit a wide range of atomizing capacities for each size atomizer. All orifices can be cleaned easily and oil and steam orifices can be changed without removing the atomizer from the burner. Precision machining of orifices assures uniform distribution to all atomizers in a zone — individual adjustments are not required.

Atomizer bodies are cast bronze; all other parts are stainless steel.

5642 Atomizers can be adapted to fit most burners, but they should not be used for low temperature furnaces or installations where cold lightings are frequent. Specify atomizer length ("L" dimension) to suit the burner involved.

Steam or compressed air should be furnished to the atomizer at 80 to 100 psi. Oil pressure at the atomizer is usually held 10 psi below the steam pressure. Line pressures must be high enough to maintain these requirements after drops through metering and control systems.

Atomizing medium consumption rates are tabulated below. These rates are at maximum atomizer capacity. At less than maximum capacity, total steam or compressed air consumption will decrease, although consumption per gallon of oil may be higher. In general, 1 pound of steam is equivalent to 20 scf of air for atomizing purposes, at the same pressures.

Atomizing Medium Required at Maximum Capacity

Fuel	lb steam/ gallon oil	scfm air/ gph oil
#2	2.5	0.925
#6	4.0	1.48

A differential steam regulator is recommended for flow control of oil/steam ratio. See Sheet 5642-1 for details.

Metric Conversions
1 psi = 0.0703 kg/cm^2
1 lb = 0.4536 kg
1 gal = 3.785 L
1 scfm = 0.000 471 sm^3/s
1 gph = 0.001 05 L/s
1" = 25.40 mm

OIL CAPACITIES

(Based on 80 psi steam pressure at atomizer and, for #6 oil, 100 SSU oil viscosity.)

Model No.	Oil Capacity, gph #2	Oil Capacity, gph #6
5642-02-5	8	5
5642-02-10	16	10
5642-02-15	24	15
5642-02-20	32	20
5642-02-25	40	25
5642-01-30	48	30
5642-01-35	56	35
5642-01-40	64	40
5642-01-45	72	45
5642-01-50	80	50

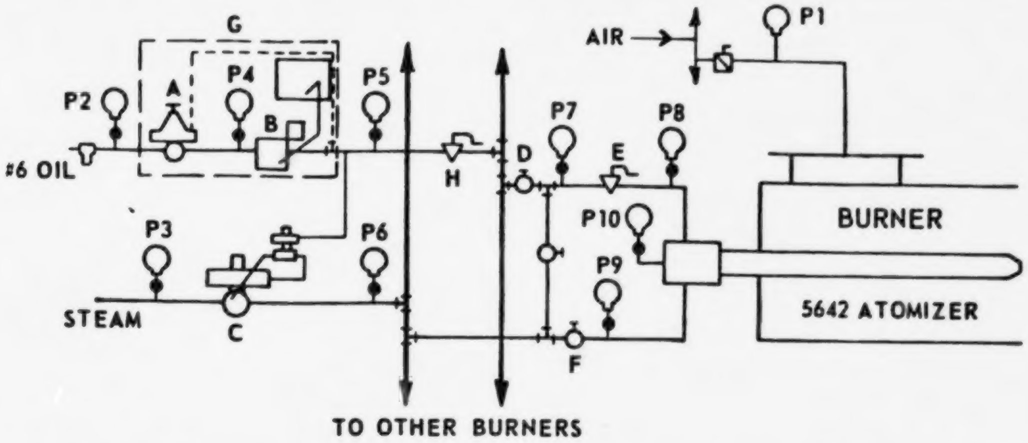
Model No.	Oil Capacity, gph #2	Oil Capacity, gph #6
5642-01-55	88	55
5642-01-60	96	60
5642-0-65	104	65
5642-0-70	112	70
5642-0-75	120	75
5642-0-80	128	80
5642-0-85	136	85
5642-0-90	144	90
5642-0-95	152	95
5642-0-100	160	100

Model No.	Oil Capacity, gph #2	Oil Capacity, gph #6
5642-1-110	176	110
5642-1-120	192	120
5642-1-130	208	130
5642-1-140	224	140
5642-1-150	240	150
5642-1-160	256	160
5642-1-170	272	170
5642-1-180	288	180
5642-1-190	304	190
5642-1-200	320	200

North American
Mfg Co
Cleveland OH 44105 USA

5642 FULL EMULSION ATOMIZERS
Instructions, Multiple Burners

Sheet 5642-1
1-69



Schematic Piping of the system usually used for reheating furnaces in the steel industry. All burners must be at same elevation.

♀ = Pressure gauge (not required at each point)
A = Oil pressure regulator
B = Adjustable port oil valve
C = Differential steam regulator (at about the same elevation as the oil header—to avoid excessive loading from the head of oil)
D = Oil shutoff valve
E = Sensitrol oil valve
F = Steam shutoff valve (wide open)
G = Positive flow oil metering system
H = Manual sensitrol, adjustable port oil valve, or good quality globe valve

Typical Operating Pressures, based on 10 #) psi steam with no oil loading:

#) steam/oil pressure differential

P1 osi	P2* psi	P3 psi	P4* psi	P5 psi	P6 psi	P7 psi	P8 psi	P9 psi	P10 psi
0.2	100	100	80	6	16	5.5	5.5	16	5
1	100	100	80	13	23	11.5	11.5	23	11
4	100	100	80	42	52	39	39	52	31
8	100	100	80	70	80	65	65	80	50

Start-up.
1. With **D** closed and no oil loading to **C**, adjust **C** to make P6 = 10 psi.
2. Open **D** and **H**.
3. Open **E** to light the burner.
4. At high fire, adjust **H** to make P5 = 70 psi.
5. Valves **E** should be wide open except when used for branch balancing.

Operation. P3 does not have to be a regulated pressure; **C** will adjust.

Readings at P10 are only approximate. The absolute pressure at P10 will be about 2/3 of the absolute pressure at P9.

Because of inlet pressures usually used, turndown ratios of more than 4 or 5 to 1 may result in several burners in a zone going out because of unbalanced flow.

Changing the head of oil (pressure) can cause readings to vary.

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*Depends on type of oil metering and control system.

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NORTH AMERICAN Mfg Co
4455 E 71 St
Cleveland OH 44105 USA

5643 TIP EMULSION ATOMIZERS

Sheet 5643-1
6-77

Series 5643 Tip Emulsion Atomizers produce flame patterns and appearances similar to those obtained with more conventional emulsion atomizers, while using only about one fourth the amount of steam or compressed air per gallon of oil atomized. Also, Series 5643 Atomizers permit quicker, clean lightups in cold settings when used in appropriate burners such as North American Series 6820 or Series 6795.

Series 5643 Atomizer Capacities and Consumption Rates

Atomizer Designation	Maximum Capacity in US gal/hr of oil	(litres/hr)	Indicator Number	Atomizing Steam Rate (No Oil Flowing) lb steam/hr at 80 psi **	(kg steam/hr at 5.6 kg/cm²)	** per lb.
5643-01	40	(150)	42	40	(18.1)	0.42
5643-0	100	(380)	165	140	(64)	0.08
5643-1	200	(760)	824	225	(102)	0.10
5643-3	400	(1520)	2400	660	(299)	0.15

Minimum oil rates are not shown since turndown is dependent on the burner in which the atomizer is used. Use the following method to determine atomizing steam rate at any oil flow rate (within the limits shown above) and at a given atomizing steam pressure (not exceeding 90 psi). Because the "Indicator Number" used is an empirical figure based on US units, all steam consumption calculations must be made in US units, and the answer converted to the metric equivalent if desired. Multiply by $^1/_3$ to convert from lb steam/hr at 80 psi to approximate scfm atomizing air at 80 psi.

Method For Determining Atomizing Steam Rate: Select the atomizer whose maximum capacity least exceeds your desired oil flow rate. Find the Oil Ratio by dividing your desired oil flow rate in gph by the Indicator Number of the atomizer selected

$$\left(\text{Oil Ratio} = \frac{\text{desired oil flow rate, gph}}{\text{Indicator Number}}\right).$$

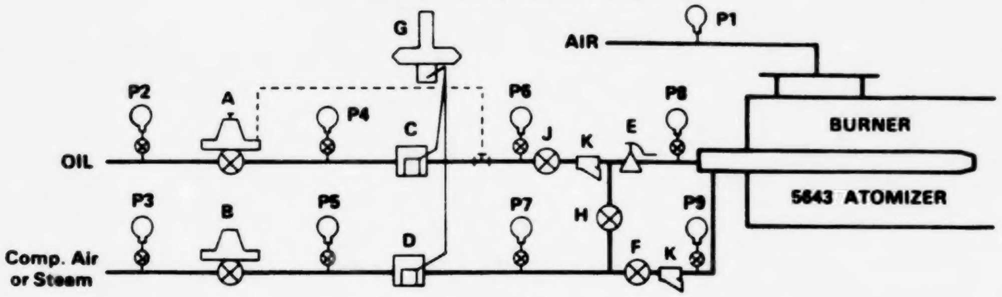
From Figure 1, find the Steam Ratio that corresponds to the Oil Ratio just determined. Multiplying the Steam Ratio times the atomizer's steam rate with no oil flowing will give the atomizing steam rate in lb/hr at 80 psi for the job at hand. To find the steam rate at pressures other than 80 psi, multiply the answer by the Correction Factor found in Figure 2 for the desired steam pressure. If using compressed air, first find the steam rate in lb/hr at 80 psi and convert the answer to scfm of air at 80 psi by multiplying by $^1/_3$. Figure 2 is used to correct for differing air pressures in the same manner as for differing steam pressures. To convert answers to metric, multiply—

lb/hr	by 0.4536	for kg/hr
scfm	by 1.698	for sm³/hr
psi	by 0.070	for kg/cm²
gph	by 3.785	for litres/hr

Example: Select an atomizer for 221 gph and determine atomizing steam consumption at 70 psi.

Solution: Choose a 5643-3 Atomizer. Oil Ratio will be 221/2400 = 0.09. From Figure 1, Steam Ratio will be 0.83. Multiplying 0.83 times 660 gives about 550 lb/hr atomizing steam consumed at 80 psi. For 70 psi steam pressure, Figure 2 shows a correction factor of 0.9, which times 550 gives a steam consumption of 495 lb/hr at 70 psi. If compressed air is used, 550 times $^1/_3$ gives 183 scfm atomizing air at 80 psi. For 70 psi multiply by 0.9 to get 165 scfm. (Multiplying 495 by $^1/_3$ also gives 165 scfm.)

INSTRUCTIONS, SINGLE BURNERS



⚲ = Pressure gauge and shutoff valve (not required at each point)
A = Oil differential pressure regulator
B = Compressed air or steam regulator
C = Adjustable port oil valve
D = Adjustable port compressed air or steam valve
E = Sensitrol oil valve (for lighting burner)
F = Compressed air or steam shutoff valve (wide open)
G = Valve operator
H = By-pass for steam purge of atomizer oil tube
J = Oil shutoff valve
K = 8558 Strainer

Installation. No air to oil ratio system is shown. Use a mass flow type of ratio controller or linked air-oil valves. Do not attempt to use a Ratiotrol. Use a 2-high linkage arrangement with separate connecting rods from **G** to **C** and **D**. **D** may operate through a smaller angle than **C**.

TYPICAL OPERATING PRESSURES in psi (kg/cm²)

% Firing Rate	P2	P3	P4	P5	P6	P7	P9 max.	P9 min.	P9 typical †
15	100 (7)	100 (7)	45 (3.2)	75 (5.3)	35 (2.5)	35 (2.5)	40 (2.8)	30 (2.1)	35 (2.5)
35	100 (7)	100 (7)	56 (3.9)	75 (5.3)	46 (3.2)	45 (3.2)	70 (4.9)	40 (2.8)	45 (3.2)
70	100 (7)	100 (7)	68 (4.8)	75 (5.3)	58 (4.1)	55 (3.9)	70 (4.9)	40 (2.8)	55 (3.9)
100	100 (7)	100 (7)	80 (5.6)	75 (5.3)	70 (4.9)	65 (4.6)	70 (4.9)	40 (2.8)	65 (4.6)

The pressure at **P8** must be slightly higher than that at **P9** to obtain oil flow.

Single Burner — Initial Start-up

1. Valve **E** must be closed.
2. Set spring in regulator **A** for maximum outlet pressure.
3. With steam flowing, set outlet pressure of regulator **B** to give desired reading at gauge **P5**.
4. Set curtain and lever of adjustable port valve **D** to give desired range of pressures at gauge **P9** during full stroke of valve operator **G**.
5. Set the curtain in valve **C** fully open.
6. Set the linkage between valve **C** and operator **G** so that full stroke of the operator results in stroking of the oil valve from approximately 1/4 open to full open.
7. Set operator **G** to minimum position.
8. Light burner by regulating Sensitrol Valve **E**.
9. Close the curtain in valve **C** while manipulating Sensitrol Valve **E** to maintain a flame. Continue until valve **E** is fully open.
10. Reduce pressure at **P4**, using regulator spring, until it is 10 psi higher than that at **P6**. During this adjustment, maintain flame by opening curtain in Valve **C** as required.
11. Drive operator **G** to high position in steps, readjusting valve **C** curtain as required to maintain flame.
12. At high valve position, make curtain adjustment for desired high firing rate.
13. Return valve to low position and adjust linkage for desired low firing rate.
14. Repeat steps 12 and 13 if necessary for desired control range.

Single Burner — Subsequent Start-up

1. Set operator **G** to minimum position.
2. Open Sensitrol Valve **E** fully to light burner.

Operation. The steam flow determines **P8** and **P9**. With no oil flow, **P9** is slightly higher than **P8**. When valve **C** opens, the oil flow increases and **P8** increases slightly. **P8** will slightly exceed **P9**.

When oil flow changes from maximum to minimum, the pressure at **P8** changes very little from the pressure at **P9**.

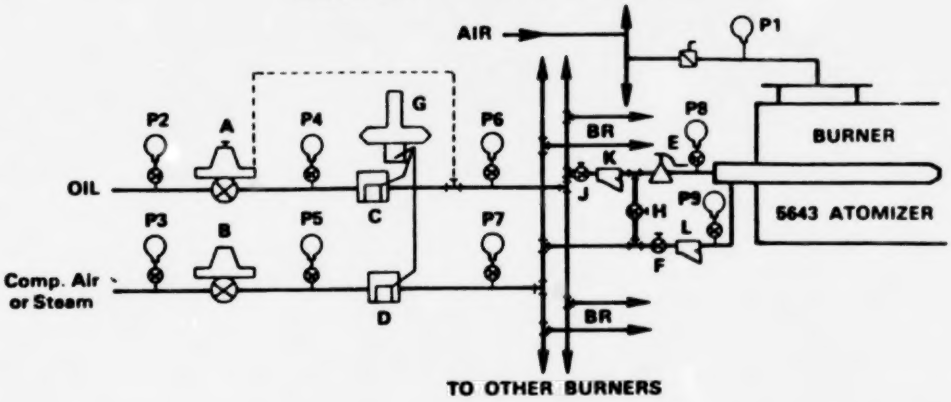
The flow rate of the atomizing agent is greatest at no oil flow and least at maximum oil flow, for the same reading of **P9**.

Changing the oil pressure at **P2** can cause readings to vary. Steam traps are necessary at all low points in the steam line. (Some steam superheat is desirable.)

---

† "Maximum" and "minimum" figures represent pressure limits for stable operation of Series 6795 Burners. To insure optimum flame geometry design system to provide "maximum" pressure. **P8** and **P9** will vary with a given installation—"typical" figures are examples of pressures that might actually be encountered on a properly set up installation.

INSTRUCTIONS, MULTIPLE BURNERS



♀ = Pressure gauge and shutoff valve (not required at each point)
A = Oil differential pressure regulator
B = Compressed air or steam regulator
C = Adjustable port oil valve
D = Adjustable port compressed air or steam valve
E = Sensitrol oil valve (for lighting burner)
F = Compressed air or steam shutoff valve (wide open)
G = Valve operator
H = By-pass for steam purge of atomizer oil tube
J = Oil shutoff valve
K = 8559 Strainer-Orifice
L = 8558 Strainer

Installation. All burners must be at same elevation. Distribution of oil and atomizing agent is important. Manifolds should be generously sized. Piping to all burners should be identical. No air to oil ratio system is shown. Use a mass flow type of ratio controller or linked air-oil valves. Do not attempt to use a Ratiotrol. Use a 2-high linkage arrangement with separate connecting rods from **G** to **C** and **D**. **D** may operate through a smaller angle than **C**.

TYPICAL OPERATING PRESSURES in psi (kg/cm²)

							P9		
%Firing Rate	P2	P3	P4	P5	P6‡	P7	max.	min.	typical†
15	110 (7.7)	100 (7)	45 (3.2)	75 (5.3)	35 (2.5)	35 (2.5)	40 (2.8)	30 (2.1)	35 (2.5)
35	110 (7.7)	100 (7)	57 (4)	75 (5.3)	47 (3.3)	45 (3.2)	70 (4.9)	40 (2.8)	45 (3.2)
70	110 (7.7)	100 (7)	72 (5)	75 (5.3)	62 (4.3)	55 (3.9)	70 (4.9)	40 (2.8)	55 (3.9)
100	110 (7.7)	100 (7)	90 (6.3)	75 (5.3)	80 (5.6)	65 (4.6)	70 (4.9)	40 (2.8)	65 (4.6)

The pressure at **P8** must be slightly higher than that at **P9** to obtain oil flow.

Multiple Burners — Initial Start-up

1. Valves **E** must be closed.
2. Set spring in regulator **A** for maximum outlet pressure.
3. With steam flowing, set outlet pressure of regulator **B** to give desired reading at gauge **P5**.
4. Set curtain and lever of adjustable port valve **D** to give desired range of pressures at gauge **P9** during full stroke of valve operator **G**.
5. Set the curtain in valve **C** fully open.
6. Set the linkage between valve **C** and operator **G** so that full stroke of the operator results in stroking of the oil valve from approzimately ¼ open to full open.
7. Set operator **G** to minimum position.
8. Light first burner by regulating Sensitrol Valve **E**.
9. Close the curtain in valve **C** while manipulating Sensitrol Valve **E** of first burner to maintain a flame. Continue until valve **E** is fully open.
10. Reduce pressure at **P4**, using regulator spring, until it is 10 psi higher than that at **P6**. During this adjustment, maintain flame by opening curtain in valve **C** as required.
11. Light additional burners by regulating their **E** Sensitrol Valves. It may be necessary to open the curtain of valve **C** to assure adequate flow to keep burners ignited.
12. Drive operator **G** to high position in steps, readjusting valve **C** curtain as required to maintain flame.
13. At high valve position, make curtain adjustment for desired high firing rate.
14. Return valve to low position and adjust linkage for desired low firing rate.
15. Repeat steps 12 and 13 if necessary for desired control range.
16. Valves **E** may be adjusted for firing profile.

Multiple Burners — Subsequent Start-up

1. Set operator **G** to minimum position.
2. Open Sensitrol Valve **E** of first burner enough to light the burner.
3. Open Sensitrol Valve **E** of second burner enough to light that burner.
4. Repeat the operation to light the remaining burners. It will be necessary to periodically increase opening of **E** Sensitrol Valves for those burners previously ignited to maintain their flames.
5. Repeat operation until all **E** Sensitrol Valves are fully opened.

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† See footnote on page 2

‡ Assuming 15 psi drop across 8559 Strainer-Orifice, Sensitrol Oil Valve "E" and interconnecting piping, at high fire

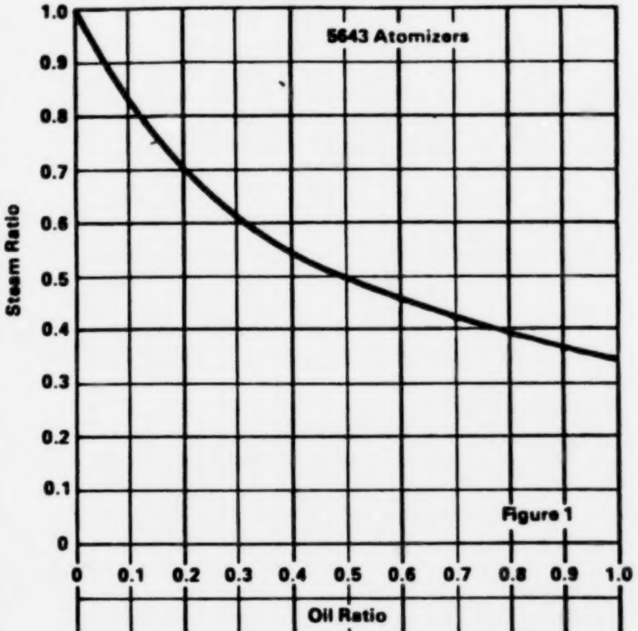

Figure 1

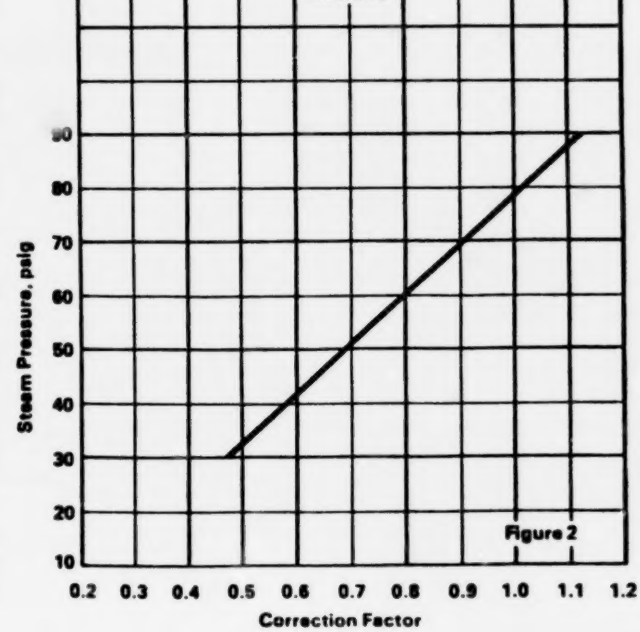

Figure 2

Operation. The steam flow determines **P8** and **P9**. With no oil flow, **P9** is slightly higher than **P8**. When valve **C** opens, the oil flow increases and **P8** increases slightly. **P8** will slightly exceed **P9**.

When oil flow changes from maximum to minimum, the pressure at **P8** changes very little from the pressure at **P9**.

The flow rate of the atomizing agent is greatest at no oil flow and least at maximum oil flow, for the same reading of **P9**.

Changing the oil pressure at **P2** can cause readings to vary.

Because of gauge inaccuracy, it is necessary to move the same gauge from point to point in order to obtain an accurate indication of relative pressures. Steam traps are necessary at all low points in the steam line. (Some steam superheat is desirable.)

Purging Atomizer

1. Close oil valve **J**.
2. Set operator **G** wide open.
3. Fully open valves **E** and **H**.
4. Throttle valve **F** until **P9** is 5 psi (0.35 kg/cm²) less than **P8**.
5. Allow sufficient time for steam to purge the oil tube and then close valves **E** and **H**.
6. Steam should continue to flow through valve **F** to purge any oil that may have been blown into the steam tube, after which valve **F** may be closed.

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North American
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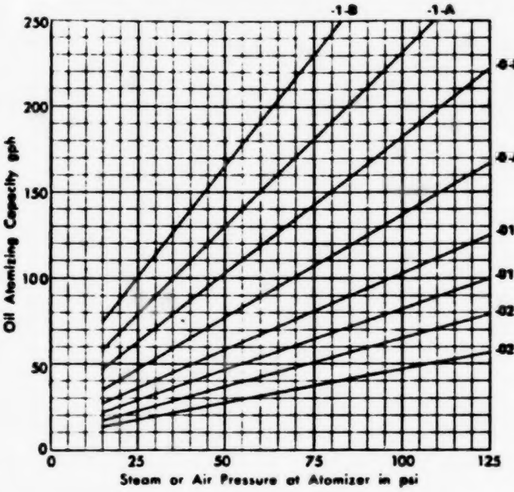
Cleveland OH 44105 USA

OIL ATOMIZERS
Steam or Compressed Air

BULLETIN 56.22
5-80 56.23



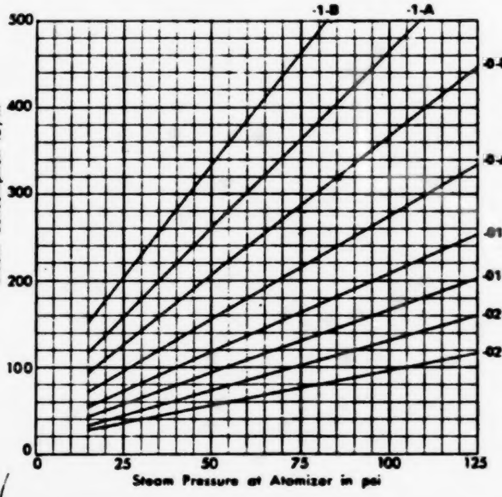
Series 5622 and 5623 Nozzle Mixing Atomizers produce 30° spray angles and fairly long flames such as required for steel mill reheat furnaces, rotary dryers, and other long combustion chambers. The stainless steel oil nozzle is concentric in the stainless steel nose, and flush with it; so steam and oil pressures do not affect each other.

Combustion air must be supplied around the atomizer. To accomplish this, the atomizers can be supplied as part of Luminous Flame Burners, Refractory-Lined Burners, or Magna-Flame Burners. By specifying the proper "L" dimension, a user can adapt the atomizers to existing burners. For installations where adequate combustion air is provided, North American can furnish a complete assembly consisting of atomizer, mounting, mounting plate, and refractory tile as shown below. Special nozzles to produce wider, shorter flames have been designed – consult North American.

Cleaning. Strainers are recommended in both the steam and oil lines. The oil nozzle of any of these atomizers is readily accessible for cleaning (with steam or a wire) by removal of a pipe plug at the back which opens a straight passage to the oil nozzle if the customer has piped the unit as shown dotted for 5622. **The quick clean-out feature of Series 5622** permits cleaning of the steam or air passage even during operation, simply by pushing the oil tube forward against an internal stop, then returning it to operating position. The outside diameter of the oil nozzle is sized to efficiently clean the inside of the steam nozzle of any carbon deposits resulting from shutdowns of steam before oil. **The quick disconnect feature of Series 5623** permits removal of the oil tube, opening a straight passage to the steam or air nozzle.

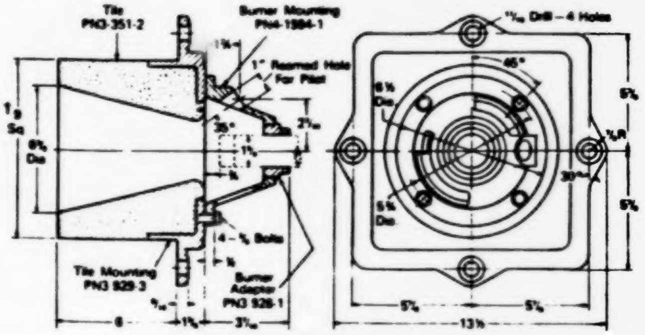
The suggested oil valve is a North American Sensitrol (brass, rated 250 psi, 275 F). The oil pressure at the oil valve inlet should be at least 5 to 10 psi (OK to use a Ratiotrol). The steam or compressed air valve is a Series 1832 Globe Valve (bronze, rated 200 psig).

Although the mountings for these atomizers provide a place for installing a 4021-14 Pilot Tip, the ability of this pilot to light the oil flame cannot be guaranteed because of the uncontrolled amount of air induced through the register.

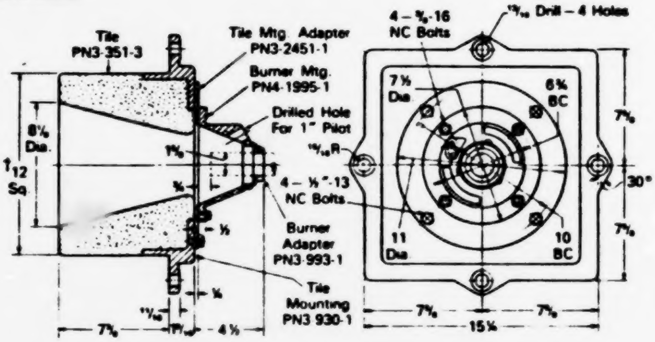


When using compressed air as an atomizing medium, air consumption in scfm is one-third of lb steam/hr for the same pressure. Example: An OB atomizer uses 285 lb/hr steam with 75 psi steam pressure or 285/3 = 95 scfm air with 75 psi air.

Dimensions in inches


Tile
PN3-351-2
Burner Mounting
PN4-1984-1
1¾
1" Reamed Hole For Pilot
†9 Sq
8⅝ Dia
35°
2⁷⁄₁₆
1⅞
⅝
4 – ⅜ Bolts
⅛
Tile Mounting
PN3 929-3
Burner Adapter
PN3 928-1
⁹⁄₁₆
6
1⅞
3⁷⁄₁₆
¹³⁄₁₆ Drill – 4 Holes
45°
6⅜ Dia
5⅝ Dia
5⅝
5⅝
⅝R
30°
5⅝
5⅝
13¼

MOUNTING for -02 and -01 ATOMIZERS


Tile
PN3-351-3
Tile Mtg. Adapter
PN3-2451-1
Burner Mtg.
PN4-1995-1
Drilled Hole For 1" Pilot
8⅝ Dia.
†12 Sq
1⅝
⅝
½
4 – ½"-13 NC Bolts
Burner Adapter
PN3-993-1
Tile Mounting
PN3 930-1
⅛
¹¹⁄₁₆
7⅝
1⁵⁄₁₆
4½
4 – ⅝-16 NC Bolts
¹³⁄₁₆ Drill – 4 Holes
7½ Dia
8¾ BC
¹³⁄₁₆R
11 Dia
10 BC
7⅝
7⅝
30°
7⅝
7⅝
15¼

MOUNTING for -0 and -1 ATOMIZERS

† Opening in furnace shell or outer wall must be ½" larger than tile dimension to allow for mounting plate fillet and draft.

NORTH AMERICAN DUAL-FUEL BURNERS MODEL 212, LOW AIR PRESSURE ATOMIZING

New Designation 65.62

NORTH AMERICAN MFG. CO.
4455 E. 71 St
Cleveland, Ohio 44105

Insert in the

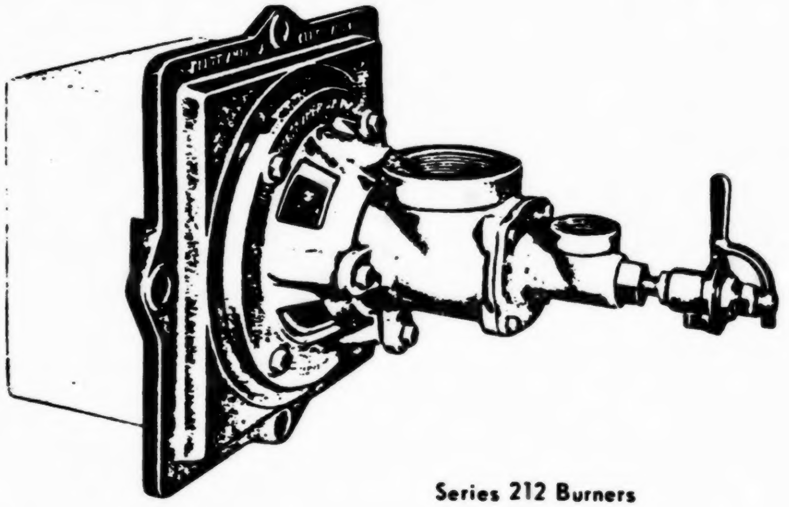
DUAL-FUEL BURNERS

section of your North American catalog

BULLETIN 212

November, 1968

Includes Parts List



Series 212 Burners

North American Series 212 Dual-Fuel Burners are designed to give maintenance-free operation using heavy oil, light oil, or gas. There are no "frills" on this burner—it has a heavy cast iron body of clean design that avoids clogging even when used on tough jobs such as forge furnaces fired with heavy oil.

North American pressure-type gas pilots are recommended for convenient, reliable ignition. Although a flame rod may be used to monitor a gas pilot on this burner, other North American Burners that permit monitoring the main flame are recommended for installations requiring flame safety.

Combustion Characteristics

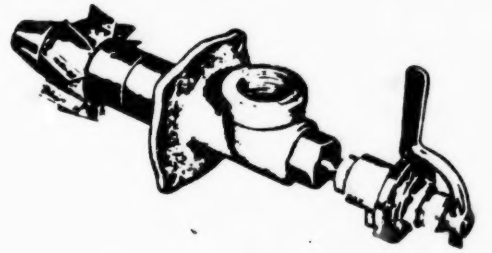
The "212" Burners provide stable combustion in a furnace having a temperature of 1600 F or higher; or in a cold furnace that has free air other than that drawn in through the burner tile. Because the burner will operate on atomizing air alone when burning oil, a 3½ to 1 turndown is possible if the air shutter is closed. Capacities shown in Table II are for operation on gas with the air shutter closed. On oil operation these capacities are increased 20% by the additional air supplied through the atomizing air connection. When burning either gas or oil with the shutter open, burner capacities may be doubled if furnace conditions assure sufficient secondary air.

Burner Operation

Oil with a viscosity of 100 to 150 SSU, and at a pressure between 25 and 30 psi, should be supplied to an Air/Oil Ratiotrol which will deliver oil to the burner at a pressure proportional to the main air pressure, thus maintaining the correct air/oil ratio at all firing rates. The atomizing air pressure at the burner may be as low as 14 osi when using distillate oil, 22 osi when using heavy oil. The "212" can operate on any gas of 500 to 3200 Btu per cu ft heating value. Gas pressure requirements are given in Table IV. Switching from gas to oil operation, or oil to gas, may be done quickly without furnace shutdown, simply by turning off one fuel valve and opening the other.

Burner Construction

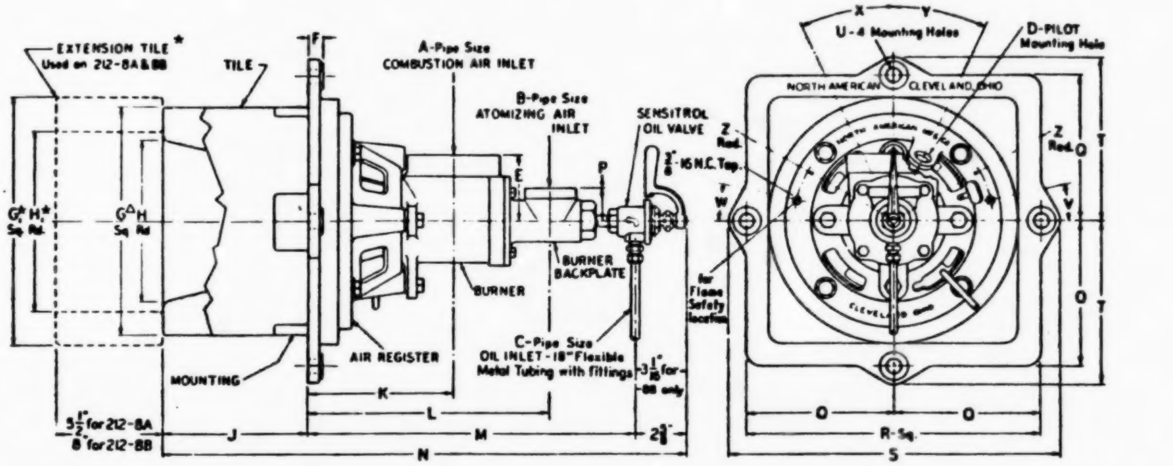
The heavy cast iron body can stand much abuse. All internal parts of the 212 Burner are machined. The smooth surfaces stay free of oil deposits and dirt, thus greatly minimizing the need for cleaning. Oil is put through the burner in a straight passage having a large cross-sectional area, permitting visual inspection for clogging; and easy clean-out if necessary.



The burner oil valve is the well-known North American Sensitrol, a non-plugging V-port oil valve which produces small and uniform flow rate changes throughout the 180° sweep of the control handle.

Piping

Series 212 Burners should be piped as shown in the instructions. If the gas pressure exceeds 2 psi, a pressure-reducing regulator should be installed upstream of the Gas/Air Ratio Regulator. The main air connection and/or the atomizing air or gas connection may be rotated in 90° increments for convenience in piping.


EXTENSION TILE *
Used on 212-8A & 8B
TILE
F
A-Pipe Size
COMBUSTION AIR INLET
B-Pipe Size
ATOMIZING AIR
INLET
SENSITROL
OIL VALVE
E
P
3/8-16 N.C. Tap.
G₁ H₁ Sq. Rd.
G H Sq. Rd.
BURNER
BACKPLATE
BURNER
AIR REGISTER
MOUNTING
C-Pipe Size
OIL INLET - 18" Flexible
Metal Tubing with fittings
3 1/16 for -8B only
K
L
5 1/2" for 212-8A
8" for 212-8B
J
M
2 3/8"
N
X
Y
U - 4 Mounting Holes
D-PILOT
Mounting Hole
NORTH AMERICAN
CLEVELAND, OHIO
Z Rad.
Z Rad.
T
W
T
V
O
T
O
T
for Flame Safety location
O
O
R-Sq.
S

Burner Designation	Dimensions in inches and degrees All dimensions except mounting holes are for estimating purposes only.																										Sensitrol Oil Valve	wt in lb	Recommended pilot size
	A	B	C	D	E	F	G^Δ	H	G₁*	H₁*	J	K	L	M	N	P	Q	R	S	T	U	V°	W°	X°	Y°	Z			
212-3	1½	1	⅜	1 1/64	1 13/16	9/16	9	6 11/16	—	—	6	5⅝	8⅝	12¾	21⅜	1¼	5⅞	11¾	13½	6¾	11/16	5°	—	20°	—	3 1/16	240-02A	64	4024-01 or 4024M-01
212-4	2	1	⅜	1 1/64	2 13/16	9/16	9	6 11/16	—	—	6	6 3/16	10⅛	14½	23⅛	1½	5⅞	11¾	13½	6¾	11/16	—	12°	—	22½°	3¾	240-02A	76	
212-5	2½	1½	⅜	1 9/64	3⅜	11/16	12	9½	—	—	13	7 9/16	12⅝	17	32⅝	1¾	7⅝	15¼	17⅛	8 9/16	13/16	10°	—	35°	—	5⅛	240-02B	185	4025-01 or 4025M-01
212-6	3	1½	⅜	1 9/64	3⅜	11/16	12	9½	—	—	13	7 9/16	12⅝	17	32⅝	1¾	7⅝	15¼	17⅛	8 9/16	13/16	10°	—	35°	-	5⅛	240-02B	185	
212-7	4	2	⅜	1 9/64	3 5/16	11/16	12	9½	—	—	13	8 11/16	14 9/16	19 5/16	34 13/16	2	7⅝	15¼	17⅛	8 9/16	13/16	12°	—	22½°	—	5 3/16	240-02C	198	
212-8A	6	3	⅜	1¾	4 9/16	13/16	15⅛	10 11/16	15½	11½	9	10 9/16	18¼	23 15/16	35 5/16	3	9¾	19½	21½	10¾	15/16	—	22°	24°	—	7½	240-02D	355	4025-1 or 4025M-1
212-8B	6	3	½	1¾	4 9/16	13/16	15⅛	11 7/16	15½	11½	9	10 9/16	18¼	24¼	36 5/16	3	9¾	19½	21½	10¾	15/16	—	22°	24°	-	7½	240-01	355	

TABLE I TOTAL AIR CAPACITIES in CFH

Burner Designation		212-3	212-4	212-5	212-6	212-7	212-8A	212-8B
Air Pressures at Burner	Combustion 12 osi; Atomizing 14 osi	4735	5935	10630	15960	23710	49425	68525
	Combustion 20 osi; Atomizing 22 osi	6320	7670	13640	20450	30460	63600	88100

The first row above of total air capacities assumes a single 16 osi blower is used to supply both combustion and atomizing air to a burner operating on light oil, while the second row assumes a single 24 osi blower is used to supply air for a burner operating on heavy oil. Use Tables II and III when selecting separate blowers for combustion and atomizing air. For sizing blowers or burners at other pressures, add figures from Tables II and III to get total air capacities.

*EXTENSION TILES, included in the price of the -8A and -8B Burners, are shipped in four pieces to avoid breakage and must be cemented together upon installation. Two complete extension tiles (8 pieces) are supplied with Burner #212-8B. Extension tiles are necessary for good operation with gas.

ΔOpening in furnace shell or outer wall must be ½" larger than dimension indicated to allow for mounting plate fillet and draft.

TABLE II COMBUSTION AIR CAPACITIES in CFH
(Not Including Atomizing Air)

Burner Designation	Air Pressure at Burner in osi												
	0.25	1	2	3	4	5	6	8	10	12	14	16	20
212-3	575	1150	1625	1900	2300	2575	2815	3250	3635	3800	4300	4600	5150
212-4	725	1450	2050	2500	2900	3250	3525	4100	4580	5000	5420	5800	6500
212-5	1156	2312	3270	4000	4625	5175	5660	6540	7300	8000	8650	9250	10350
212-6	1787	3575	5050	6200	7150	8000	8750	10100	11300	12400	13375	14300	16000
212-7	2812	5625	7950	9750	11250	12600	13775	15900	17800	19500	21050	22500	25200
212-8A	5125	10250	14500	17700	20500	23000	25100	29000	32400	35400	38300	41000	46000
212-8B	7875	15750	22300	27250	31500	35250	38550	44500	49750	54500	59000	63000	70500

For Burner Capacities in Btu per hour, multiply above figures by 100.

Btu capacities in Table II are based on supplying 100% air for combustion through the burner when operating on gas with the shutter closed. When operating on oil Btu capacities may be increased at least 20% because of the additional air supplied through the atomizing air connection. For either gas or oil operation, Btu capacities may be doubled with the shutter open, provided furnace conditions assure sufficient secondary air. In actual practice, few furnaces do supply sufficient secondary air to double Btu capacities, but a capacity increase of 30% to 40% can be expected in most cases.

TABLE III ATOMIZING AIR CAPACITIES in CFH

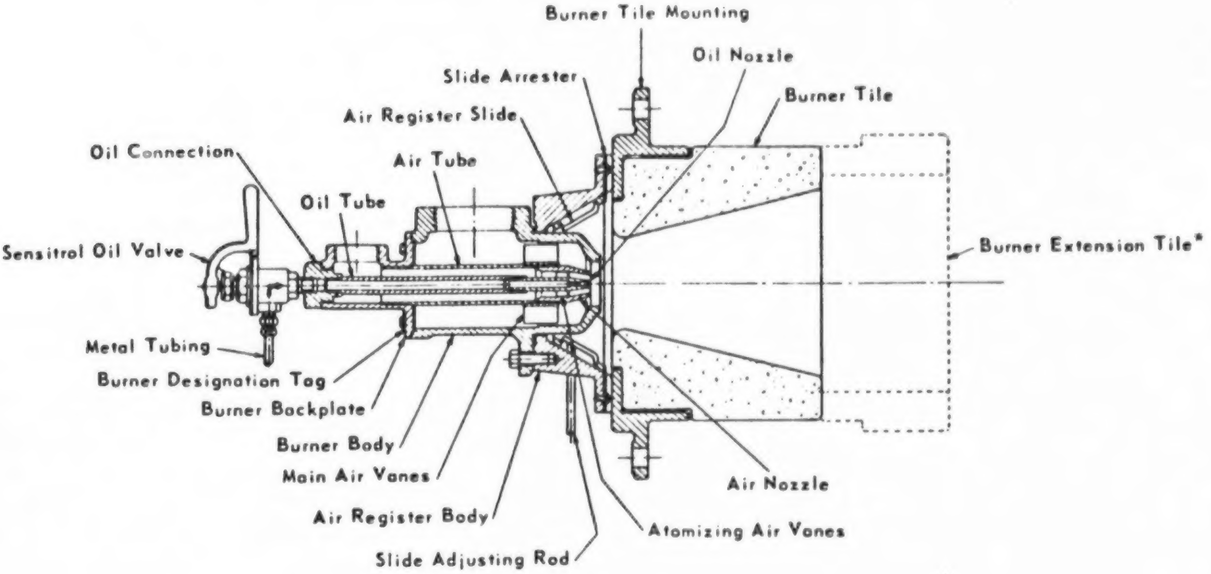
Burner Designation	Air Pressure at Burner in osi					
	14	16	18	20	22	24
212-3	935	1000	1060	1120	1170	1220
212-4	935	1000	1060	1120	1170	1220
212-5	2630	2810	2980	3150	3290	3430
212-6	3560	3800	4030	4260	4450	4640
212-7	4210	4500	4780	5050	5260	5500
212-8A	14025	15000	15900	16800	17600	18300
212-8B	14025	15000	15900	16800	17600	18300

TABLE IV GAS PRESSURE FACTORS

Burner Designation	1000-1100 Btu/cu ft 0.6 sp gr		800-900 Btu/cu ft 0.55 sp gr		500-550 Btu/cu ft 0.4 sp gr	
	Capacities shown in Table II	Double Capacities shown in Table II	Capacities shown in Table II	Double Capacities shown in Table II	Capacities shown in Table II	Double Capacities shown in Table II
212-3	.19	.63	.27	.93	.37	1.34
212-4	.28	.88	.38	1.29	.53	1.88
212-5	.15	.48	.21	.71	.29	1.01
212-6	.21	.67	.29	.99	.40	1.42
212-7	.20	.65	.39	1.15	.51	1.63
212-8A	.24	.41	.28	.53	.35	.83
212-8B	.31	.66	.37	.90	.45	1.23

Multiply the air pressure at the burner by the appropriate factor listed above to find a gas pressure at the burner sufficient for all burner operating conditions. Factors for propane and butane would be smaller than any shown in table.

PARTS LIST–Series 212 Dual-Fuel Burners


Burner Tile Mounting
Oil Nozzle
Slide Arrester
Burner Tile
Air Register Slide
Oil Connection
Air Tube
Oil Tube
Sensitrol Oil Valve
Burner Extension Tile*
Metal Tubing
Burner Designation Tag
Burner Backplate
Burner Body
Main Air Vanes
Air Nozzle
Air Register Body
Atomizing Air Vanes
Slide Adjusting Rod

ORDER MUST SPECIFY: ① Burner Designation from tag ② Part Name ③ Part Number
④ Either date of original burner purchase or original shop order number

Burner Designation	212-3	212-4	212-5	212-6	212-7	212-8A	212-8B
Part Name	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.	Part No.
Air Nozzle Air Tube	3-1672	3-1673	3-1675-3	3-1675-1	3-1675-2	3-1754-2 3-1753-1	3-1754-2 3-1753-1
Air Register Body	3-946-1	3-948-1	3-2112-1	3-2112-1	3-2122-1	3-932-4	3-932-4
Air Register Slide	3-945-1	3-947-1	3-2102-1	3-2102-1	3-2103-1	3-933-2	3-933-2
Atomizing Air Vanes	—	—	—	—	—	3-2082-3	3-2082-3
Burner Backplate	3-1552-2	3-1581-1	3-1612-1	3-1612-1	3-1633-2	3-1752-1	3-1752-1
Burner Body	3-318-1	3-320-3	3-2287-2	3-321-1	3-322-1	3-323-6	3-323-7
er Tile	3-351-2	3-351-2	3-1403-1	3-1403-1	3-1403-1	3-351-5	3-351-6
Burner Tile Extension *	—	—	—	—	—	4-4180-2	4-1737-7 (2 req'd.)
Burner Tile Mounting	3-929-1	3-929-2	3-930-3	3-930-3	3-930-4	3-931-3	3-931-3
Metal Tubing	3-310-7	3-310-7	3-310-7	3-310-7	3-310-7	3-310-7	3-310-8
Main Air Vanes	3-1055-2	3-1658-8	3-1658-9	3-1658-9	3-1658-10	3-1658-11	3-1658-11
Oil Connection	3-1608-1	3-1584-1	3-1613-1	3-1613-1	3-1613-2	3-1663-1	3-1663-1
Oil Nozzle	3-1732-1	3-1732-1	3-1737-1	3-1737-1	3-1191-1	3-879-4	3-879-4
Oil Tube	3-1611-1	3-1582-2	3-1655-4	3-1655-3	3-1655-2	3-1757-1	3-1757-1
Sensitrol Oil Valve	240-02A	240-02A	240-02B	240-02B	240-02C	240-02D	240-01
Slide Adjusting Rod	3-892-1	3-892-2	3-892-3	3-892-3	3-892-3	3-892-3	3-892-3
Slide Arrester	3-951-1	3-951-1	3-951-2	3-951-2	3-951-2	3-951-2	3-951-2
Tile Mtg. Hooks (pair)	—	—	3-1398-1	3-1398-1	3-1398-1	—	—

*EXTENSION TILES, included in the price of the -8A and -8B Burners, are shipped in four pieces to avoid breakage and must be cemented together upon installation. Two complete extension tiles (8 pieces) are supplied with Burner #212-8B. Extension tiles are necessary for good operation with gas.

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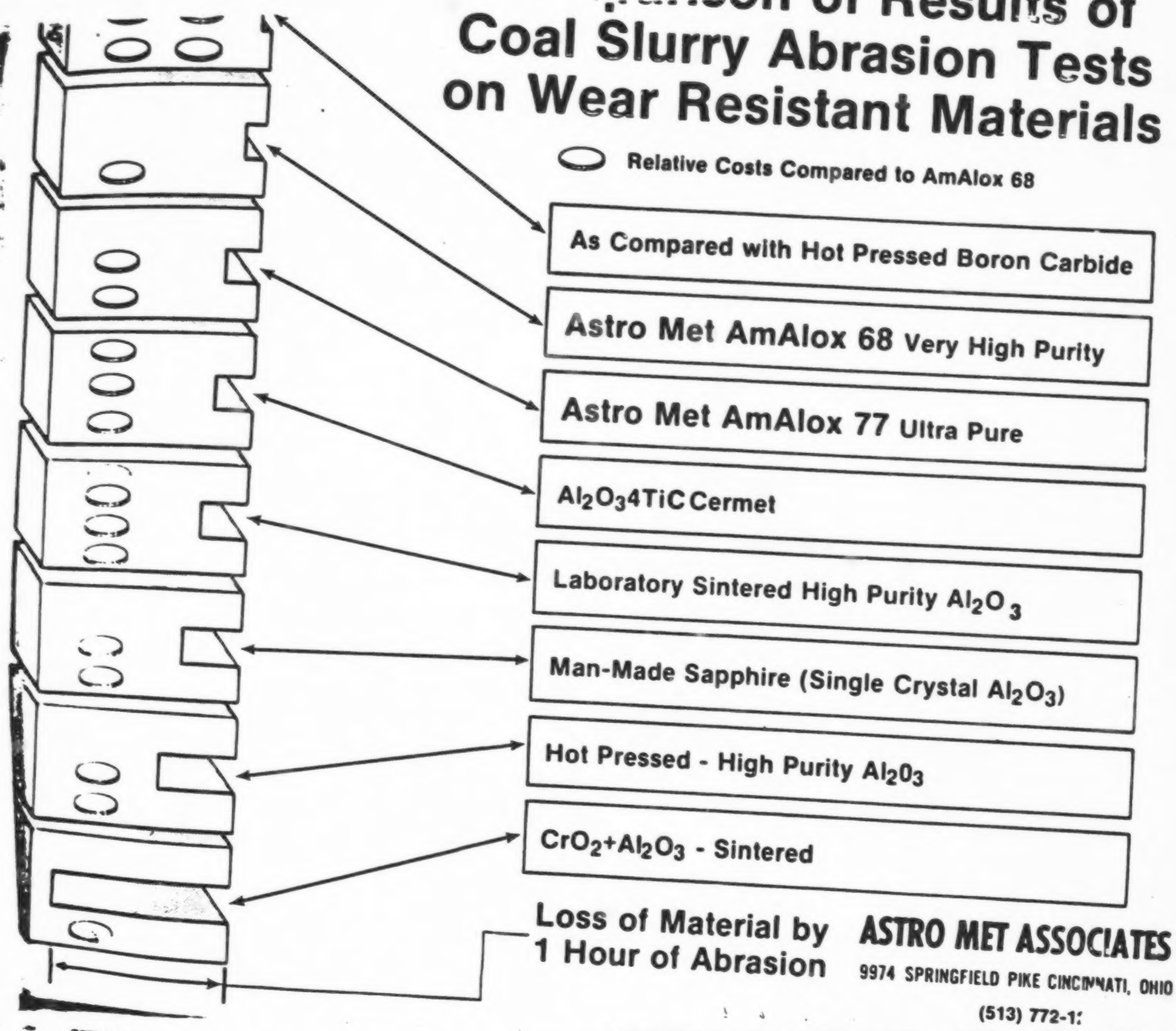
Results of Coal Slurry Abrasion Tests on Wear Resistant Materials


Relative Costs Compared to AmAlox 68
As Compared with Hot Pressed Boron Carbide
Astro Met AmAlox 68 Very High Purity
Astro Met AmAlox 77 Ultra Pure
Al_2O_34TiC Cermet
Laboratory Sintered High Purity Al_2O_3
Man-Made Sapphire (Single Crystal Al_2O_3)
Hot Pressed - High Purity Al_2O_3
$CrO_2+Al_2O_3$ - Sintered
Loss of Material by 1 Hour of Abrasion

ASTRO MET ASSOCIATES INC.

9974 SPRINGFIELD PIKE CINCINNATI, OHIO 45215

(513) 772-1

BULLETIN NO. 10

AECO

Rotary kiln burner system

AECO Rotary kiln burner system

The AECO Rotary Kiln Burner System is an advanced, high-performance total package designed specifically for the rotary kiln drying, calcining and/or burning processes.

The key to the system is a new and advanced burner that was developed as a result of ten years research into kiln combustion problems.

The new burner gives improved combustion performance while reducing fuel consumption rates and providing additional energy savings resulting from lower oil and air pressure requirements. Today, with rising fuel costs and shortages, energy savings are becoming increasingly important.

The improved combustion performance can also result in better product quality, higher production, longer refractory life, reduced shell heat losses, the elimination of rings and reduced waste combustibles.

Applications for the system include the processing of lime, limestone, lime sludge, cement, alumina, magnesite and light-weight aggregates.

Main features

Optimum flame characteristics

For high performance and combustion efficiency, optimum flame characteristics are vitally important. With the AECO system, the flame is thin and pencil-like throughout the burning zone of the kiln. This provides highly efficient heat transfer (by both radiation and convection) over a longer length of the kiln load.

The narrow combustion configuration greatly reduces flame impingement on the kiln lining and product. Wasteful kiln heat losses are therefore reduced. This saves valuable fuel energy while enhancing product quality.

The adjustable flame lengths greatly exceed usual kiln requirements. Also, the flame cross-sectional area is highly uniform over the full flame length, and this uniformity is not adversely affected by flame length adjustments.

Reduced energy requirements

The total energy required to operate the complete system is substantially below that required by all comparable burner systems on the market.

The main reasons for this are higher combustion performance and substantially improved flame configuration. A second reason is that other systems require higher oil pressures and/or higher primary-air volumes. Lastly, other systems use single-stage mechanical or steam atomization whereas the AECO system uses two-stage atomization. This gives a greatly reduced oil particle size of approximately 10 microns.

To date, installations have given proven energy savings of 5-10% in fuel consumption alone. With kilns utilizing heat-recovery systems, further energy savings are possible since the primary air requirement can be eliminated.

Advanced control system

An advanced control system modulates the opening of the tangential holes to the swirl chamber via an oil-flow control rod. The system provides turn-down ratios of up to 20:1. This broad turn-down range allows the kiln to be fired from cold start-ups to full operation without nozzle changes.

The control involves constant pressure and variable orifice size rather than the variable pressure and constant orifice size of less advanced designs.

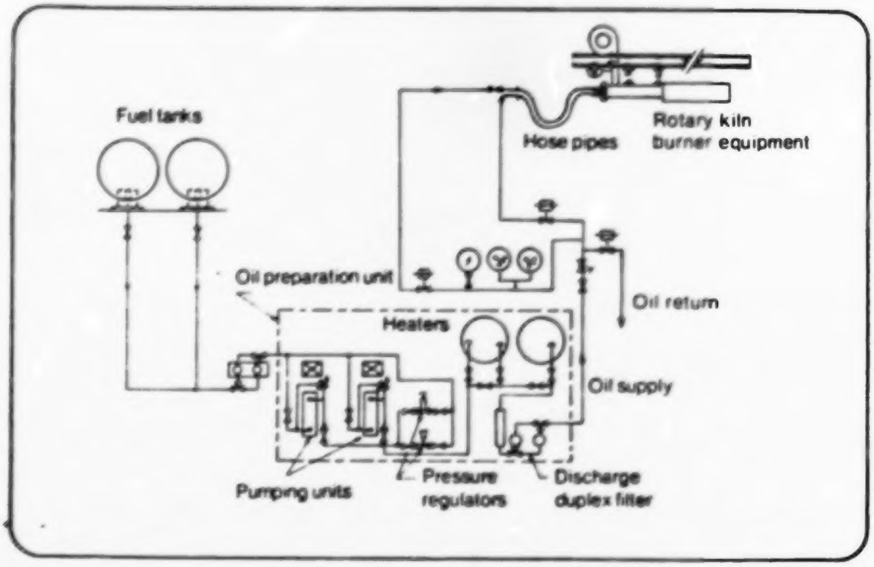
The fuel rate can be manually or automatically adjusted by means of a reversing-type stall motor.

Less maintenance

The burner nozzle components, which are exposed to radiant heat, do not suffer from carbon build-up because the components are not subjected to fuel wetting. As coking is therefore eliminated, the burner seldom requires cleaning between scheduled shut-downs.

Fully engineered package

The AECO Rotary Kiln Burner System can be supplied as a fully engineered package, complete with burner, oil and/or gas valve trains, atomizing air blower, flame safeguard control panel package, pre-piped supply-oil pumping units, and all necessary pumping, heating and circulating equipment.



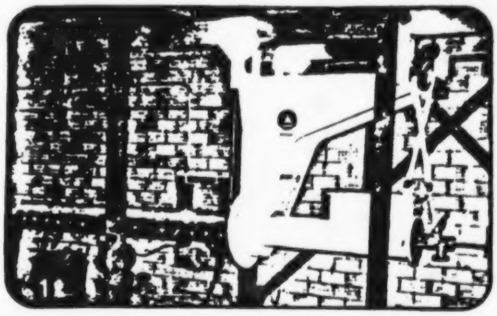
Typical plant fuel distribution system incorporating all necessary equipment from fuel unloading to points of fuel use.

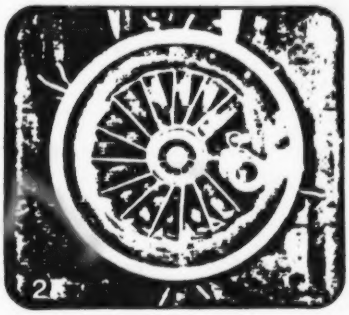
In summary, the main features are:

- Reduced energy requirements
- Reduced kiln heat losses
- Higher efficiency atomization
- Increased combustion performance
- Improved heat transfer to kiln load
- Turn-down ratios of up to 20:1
- Cold start-ups without nozzle changing
- Reduced burner maintenance
- Fully engineered package

Photos

1. *AECO Rotary Kiln Burner complete with overhead carriage. Floor carriage and pantographic hood mountings are also available.*
2. *Burner End View of AECO Kiln Burner showing main oil nozzle, pilot and high-energy ignitor assembly.*
3. *AECO Rotary Kiln Burner being test-fired before shipment to job sight.*





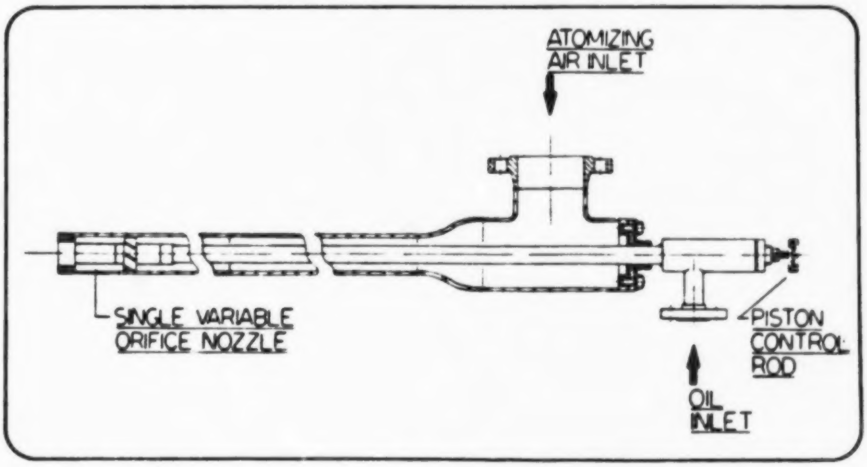
Burner design principles

The design principles of the burner are shown in the schematic drawing. Atomization is achieved in two, internal stages:

In *stage 1*, oil, pumped at a *relatively-low, fixed pressure* (400 psi at the burner), is atomized in a wide angle spray. The oil emerges from tangential orifices at high pressure, thus achieving a standard mechanical type of atomization.

In *stage 2*, the wide-angle spray of oil is intercepted by a *low-pressure* (3 - 4 psi) air column, which changes the direction of and further shatters the oil particles into a very fine and narrow spray.

The total air requirement for atomization is 2%, or less, of primary air.



Schematic of standard kiln burner gun

Gas and combination systems

Gas and combination burner systems are also supplied, and are engineered to best suit the process and available gas pressures. The systems are extremely versatile, being capable of operating under any of the following four conditions:

1. Low-pressure gas using atomizing air in place of primary air.
2. High-pressure gas, eliminating the atomizing air
3. Simultaneous firing of gas and oil, utilizing gas as the oil-atomizing medium.
4. Simultaneous firing of gas and oil, utilizing low-pressure air as the oil-atomizing medium.

Combination burner systems allow changeovers from gas to oil, and vice-versa, without any need for burner shut-downs

Plant fuel-distribution systems

In addition to the Rotary Kiln Burner System, AECO designs and engineers total plant fuel distribution systems incorporating all necessary equipment from fuel unloading to points of fuel use.

About Conamara
Conamara Limited specializes in the design, engineering and manufacture of AECO industrial process heaters (hot-air generators) and AECO combustion equipment, rotary kiln burners and fuel-handling systems.

CONAMARA LIMITED

2180 Speers Road, Oakville, Ontario
Canada L6L 2X8
Telephone: (416) 825-1400
Telex: 06-982389

CEA Type DV(double vortex) Burner/ Combustor for Pellet Firing

Trash-to-fuel

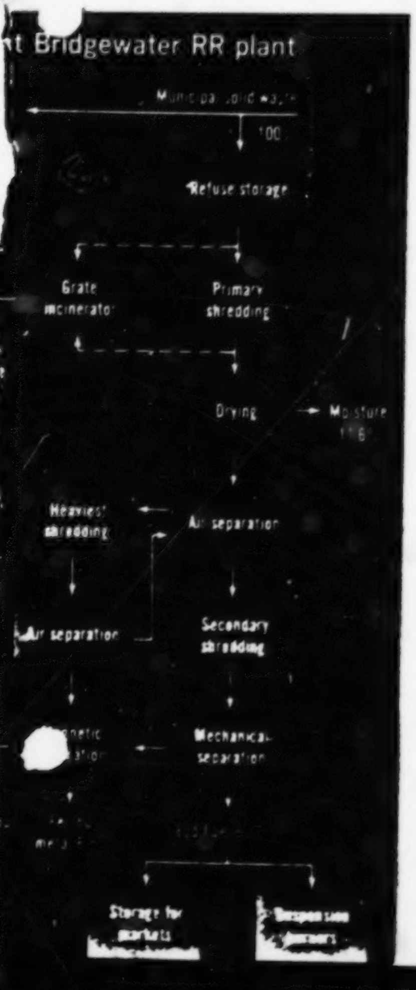
The new idea is to first convert the solid waste into a self-sufficient fuel before being used by an electric utility. This process surpasses the trash-to-power method, which, in the case of [illegible] Louis, provided only 10% of the total heat input needed.

Certain demonstration projects have proved the feasibility of going directly from trash to fuel. Examples that come to mind are Union Carbide's 5-tpd pilot plant in Tarrytown (N.Y.), and joint lab studies by York Research and Combustion Equipment Associates in Stamford (Conn.). As a result, the process has gone commercialized.

Some companies are building facilities which will convert refuse to a fuel gas by pyrolysis—a method of chemical decomposition by heat. These include Monsanto Enviro-Chem Systems, Inc. (Baltimore, Md.), Garrett Research and Development Co. (San Diego, Calif.), and Union Carbide (Charleston, S.C.).

CEA concept

A step ahead of the fuel game, Combustion Equipment Associates has developed a process for deriving a solid fuel from solid wastes. Their $10 million, 1200-tpd East Bridgewater, Mass. plant was opened for business last October.



t Bridgewater RR plant

center. Wastes are picked up by specially equipped front-end loaders, passed through a conveyor system, and fed to primary shredders. They are dried and classified in an air separator in which a light combustible fraction is separated from the heavier noncombustible fraction containing ferrous and nonferrous materials.

The heavy fraction is further shredded and classified to segregate any remaining combustibles which are then recycled to the first air separator. The separated heavies are combined with the noncombustibles; ferrous metals (6.5% of total wastes) are recovered by magnetic separation and sold; nonferrous materials (14.2% of total) such as glass, dirt, aluminum, zinc, lead, and copper are sterilized for clean fill or further processed for recovery.

The light fraction is reduced further in size and fed to a mechanical separator to remove the rest. The final product (67.7% of total) is a solid "fuel."

Eco-Fuel

This refined combustible fraction recovered from municipal solid waste is:

- a grayish substance with popcorn consistency
- $\frac{1}{2}$-in particle size
- 7–10 lb/ft^3 in density
- low in sulfur content
- 78.5% combustibles (paper, wood, leather, rubber, plastics, textiles, food and yard wastes), 11.5% ash, and 10% moisture
- high in heating value—6900 Btu/lb
- odor free
- stable over an indefinite storage period

Fired in a specially designed CEA double-vortex burner coupled to an existing boiler, Eco-Fuel will generate as much steam as pulverized coal, on an equivalent weight basis. The nature and amount of fly ash from coal or Eco-Fuel are comparable. Particulate removal in both instances is easily affected by electrostatic precipitators or fabric filters.

Eco-Fuel mixes well with combustion air because of its physical characteristics, achieving a less than 8-ppm carbon monoxide equilibrium concentration at furnace exit temperatures of 2100–2300°F. It also burns at a lower adiabatic flame temperature, so that NO_x emissions are lower than those from coal-fired boilers.

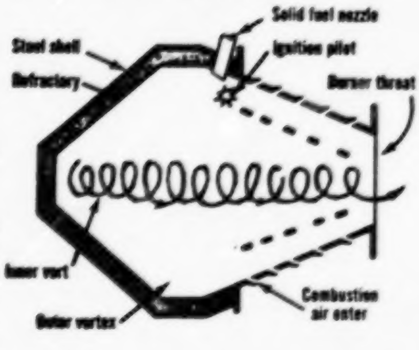
DV burners

This double-vortex system combines turbine technology with suspension fuel burning and is recom-

r optimal performance of The CEA design allows uel combustion with minimal emissions, thereby releasing more heat.

The burner, a double cone-shaped combustion chamber with one end closed and the other opened to exhaust the combustion gases, is housed within a windbox into which fuel and combustion air enter tangentially. The mixture spirals toward the closed end in an outer vortex before reversing travel toward the open end in an inner vortex. Larger fuel particles are recirculated back into the outer vortex for complete burning.

Double-vortex burner



Source: CEA

In a nutshell, the solid fuel is converted to a gas, mixed with air, heated to ignition temperature, and oxidized. Exit gases are clean. Ash and slag are removed by an ejection system within the burner, eliminating the need for a secondary collection unit.

Everybody benefits

Conservative estimates point out that as much as 10% of the U.S. power requirements can be met with garbage. Towns can be rid of their unsightly garbage at costs comparable to what they are now paying for dumping. Any enterprise can build these refuse processing plants with private financing. Take the case of CEA, their East Bridgewater facility charges $9.25/ton refuse. This sum is sufficient to amortize the 20-yr investment of $10 million. CEA can also profit by selling the end product marketed as Eco-Fuel; ideally, to a utility in close proximity to the refuse plant, thus minimizing transportation costs. It has recently signed a 10-year contract with Weyerhaeuser Corp. (Mass.). The latter has agreed to purchase over 770,000 tons of Eco-Fuel, roughly equivalent to 2 mbbl of oil for use in one of its boiler plants. The not so tasteful subject of garbage has become a good conversation piece.

LCG

PAT REPORT
PRACTICAL, AVAILABLE TECHNOLOGY

Sonic gas cooling systems cut . . .

Sonic Development Corp.'s units cool hot effluent gases from smelters in Arizona and asphalt roofing plants in Los Angeles

Optimum performance of air pollution control equipment with minimum maintenance cost requires more careful attention to preconditioning of the effluent gases. The use of ultrafine water sprays is helpful in pretreating gas stream to enhance the collection efficiency and reliability of the air pollution control system. Recently developed sonic atomizing nozzles and computerized analysis of gas conditioning problems permit the design of automated systems for cooling hot effluent gases. Such systems can be used to upgrade existing installations or to reduce the size and cost of new installations.

Sonic evaporative cooling equipment from Sonic Development Corp. (Upper Saddle River, N.J.) is now operating in numerous foundries, smelters, liquid waste incinerators, and various industrial furnaces with excellent results. In a typical application, sonic atomizing nozzles were installed in a cooling chamber at the Hayden, Ariz., facility of Kennecott Copper Corp. with the basic work handled by the plant engineering staff and operating personnel.

James Stocker, smelter operations superintendent at the Hayden operation, says that off-gases from the fluidized bed reactor are cooled from 1100–800°F before cleanup by an electrostatic precipitator. As originally designed, the cooling chamber used 30 conventional spray nozzles operating at hydraulic pressures up to 350 psig. Two sonic nozzles replaced the 30. The finer atomization delivered by these nozzles provided total water evaporation and eliminated the earlier experiences of wet chamber bottoms, sludge buildup, and unscheduled shutdowns. Stocker says the nozzles at the Hayden facility were installed in 1970, and in the past three years have saved many thousands of dollars by reducing plant downtime.

What is useful to smelter operators has been found useful by other manufacturing operations including asphalt roofing plants. For example, the Celotex Corp. recently installed a sonic gas cooling system in their Los Angeles asphalt roofing plant to cool hot gas fumes before cleaning by a Johns-Manville high-energy air filter (HEAF).

According to Lloyd Pfaff, senior project engineer for the Celotex Corp., the sonic system cooled 22,000 acfm from 150–130°F—the optimum temperature for efficient filtration by the glass fiber media. "Without the fine atomization of the sonic nozzles," Pfaff reports, "evaporative cooling could not have been accomplished in the existing ductwork within the available residence time of 1.6 sec. The sonic atomizing system enabled us to avoid costly shutdowns and satisfy EPA regulations."

Why spraying?

In evaporative cooling, water injected into a hot gas stream evaporates and absorbs heat from the gas. Virtually every problem associated with evaporative cooling systems is traceable in some way to the nozzles used to inject water into the gas stream. The low-cost pressure nozzle commonly used in such systems is inherently incapable of producing the ultrafine droplets required for evaporation and cooling. Large water droplets produced by such nozzles agglomerate with dust particles to form sludge or pass through the cooling chambers to foul collection equipment.

The large droplets also cause localized cooling resulting in refractory spalling and severe distortion of sheet metal ducts. The small orifi[illegible] required for pressure nozzles [illegible] frequently and wear rapidly causing high maintenance costs and frequent shutdowns. Lacking turndown capability, pressure nozzles cannot be modulated to suit varying inlet temperatures but must be actuated separately or in banks to achieve even crude flow modulation.

To compensate for the poor atomization, designers must often increase the required water volume by 50% to allow a "safety" factor, thus further compounding nozzle problems and creating a secondary water pollution problem. The combination of poor atomization, erratic cooling, and slow system response is often the cause of baghouse fires and precipitator malfunctions. These severe field problems clearly indicate the need for more sophisticated and reliable gas cooling equipment.

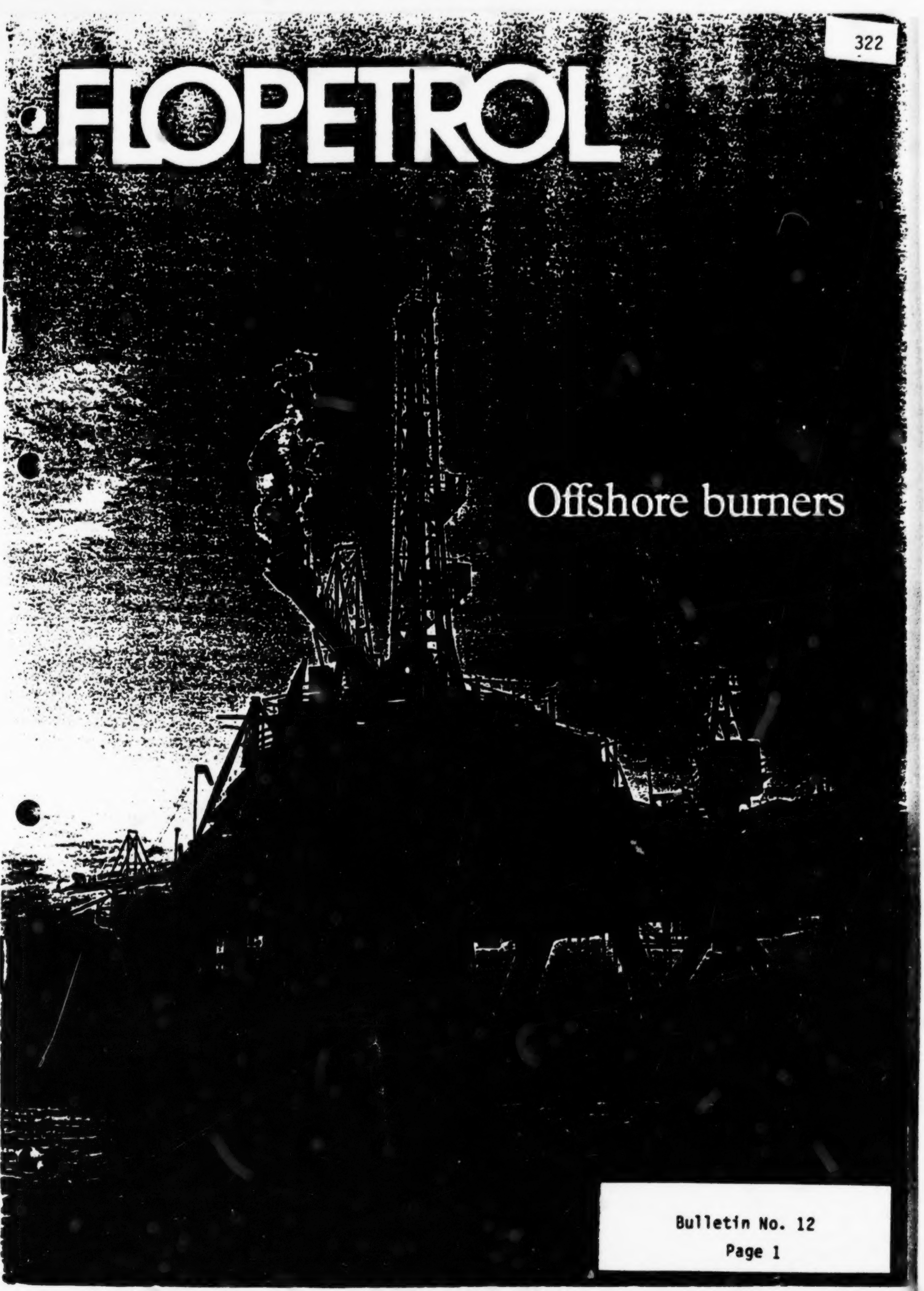
Preconditioning

In addition to cooling hot gases, fine water sprays also play a critical role in the preconditioning of the gas stream and significantly affect the performance and efficiency of the pollution control equipment. W[illegible] electrostatic precipitators, efficie[illegible] of collection is a function of the electrical resistivity of dust particles.

Many dusts, such as glass and cement, have inherently high resistivi-

Kennecott's Stocker
"Nozzles . . . have saved many thousands of dollars . . ."

FLOPETROL



Offshore burners

MAIN FEATURES

- Compact
- Light-weight
- No moving parts
- No fan

The Flopetrol burner comprises:

Combustion head(s)

The Flopetrol burner is made up of one or several combustion heads.
The combustion head is designed to dispose of the following effluents, in complete safety, without polluting the environment:
crude oil
invert oil base mud
foam.

The presence of solid particles in the effluent does not affect burning operations.
Each combustion head includes:

An Atomizer ①

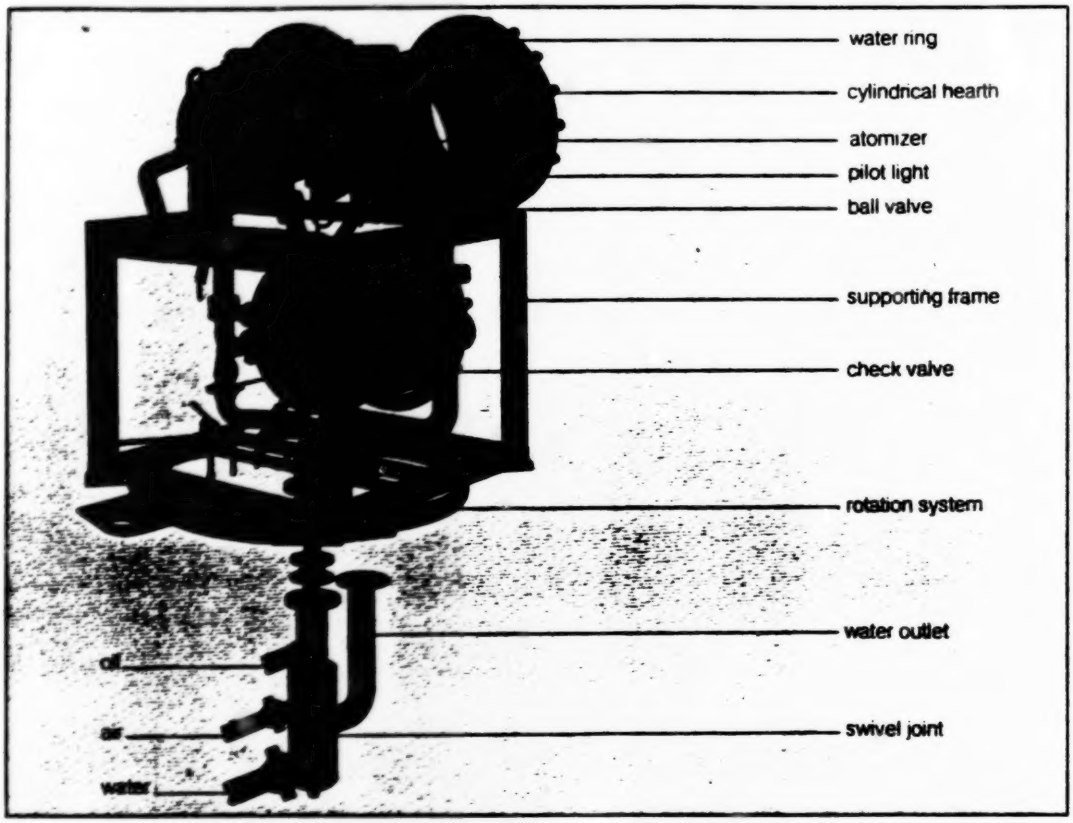
In order to obtain efficient combustion to the effluent produced:
i.e. no fall-out of unburnt particles
no heavy black smoke
it is mandatory to reduce the effluent to very fine droplets.

This operation, called atomization, is achieved by:
- using the energy resulting from the pressure of the effluent (mechanical)
- supplying additional energy, either air or gas available on the rig (pneumatic).

The final atomization is the result of these two processes, the former predominating at high flow rates, the latter at low flow rates.

To avoid any risk of plugging, the atomizer has been designed to allow the passage of solid particles up to 1/4" in diameter. The atomizer can be easily replaced (quick union).

MAIN FEATURES


water ring
cylindrical hearth
atomizer
pilot light
ball valve
supporting frame
check valve
rotation system
water outlet
swivel joint
oil
air
water

A Cylindrical Hearth ②

Which stabilizes the flame and facilitates the circulation of combustion air.

A Pilot Light System ③

comprising:

- a gas pilot light fed with propane, butane, or gas from separator
- a remote-controlled electric igniter unit with spark plug.

As an option, a diesel oil pilot light fed from an air-driven pumping unit can be supplied.

A water Ring ④

With special nozzles injecting water inside the flame. Water sprayed into the flame modifies the quality of combustion, avoids the formation of heavy smoke and decreases the radiated heat.

Supporting frame

This supports the atomizer, cylindrical hearth, piping, swivel and pilot light system.

Swivel joint

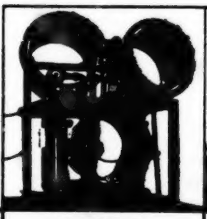
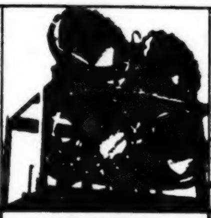
For complete safety, oil, air, gas and water are supplied through check valves to a vertical swivel joint distributor which enables the burner to be oriented to suit the wind direction.

Rotation system

The supporting frame is mounted on a rotation system, actuated by cable and a hand winch from the foot of the boom. An optional pneumatic rotation kit can be supplied for remote-control from the platform or rig. Maximum rotation : 150°.

Ball valves on the air and oil pipes make it possible for the operator to select the number of heads to be used.

SPECIFICATIONS

				
TYPE	SEADRAGON THREE HEADED UNIT	SEADRAGON FOUR HEADED UNIT	SPITFIRE	MUD BURNER
Assembly number	M 801 251	M 803 895	M 808 872	M 808 206
Oil flow rate				
(GOR = O) at 200 psi	7500 BOPD (1192 m^3/d)	10500 BOPD (1669 m^3/d)	3100 BOPD (493 m^3/d)	max. 5000 BPD (795 m^3/d) (150 to 600 psi)
(Oil = API 32°) at 350 psi	10000 BOPD (1590 m^3/d)	13300 BOPD (2115 m^3/d)	4000 BOPD (636 m^3/d)	
at 465 psi	12000 BOPD (1908 m^3/d)	16000 BOPD (2544 m^3/d)	5000 BOPD (795 m^3/d)	
Minimum flow rate per head	100 BOPD (159 m^3/d)	100 BOPD (159 m^3/mm)	100 BOPD (159 m^3/d)	100 BPD (159 m^3/d)
Air supply				
– pressure	50 to 100 psi	50 to 100 psi	50 to 100 psi	50 to 100 psi
– flow rate	350 cu. ft/mn(9.91 m^3/mn)	350 cu. ft/mn (9.91 m^3/mn)	350 cu. ft/mn (9.91 m^3/mn)	350 cu. ft/mn (9.91 m^3/mn)
Water supply				
– maximum pressure	300 psi (20.68 bar)	300 psi (20.68 bar)	300 psi (20.68 bar)	350 psi (24.12 bar)
– maximum flow rate	18,000 BWPD (2862 m^3/d)	24,000 BWPD (3816 m^3/d)	4,500 BWPD (715 m^3/d)	18,000 BWPD (2862 m^3/d)
Pilot light				
– Ignition	Propane, gas or diesel oil Supply: 110 VAC or 200 to 250 VAC 50 or 60 Hz	Propane, gas or diesel oil Supply: 110 VAC or 200 to 250 VAC 50 or 80 Hz	Propane, gas or diesel oil Supply: 110 VAC or 200 to 250 VAC 50 or 60 hz	Prropane, gas or diesel oil Supply: 110 VAC or 200 to 250 VAC 50 or 60 Hz
Rotation device	One swivel joint allowing a rotation of 75° each side of boom center line	One swivel joint allowing a rotation of 75° each side of boom center line	One swiver joint allowing a rotation of 75° each side of boom center line	one swivel joint allowing a rotation of 75° each side of boom center line
Connections				
– Oil	3" LP	3" LP	3" LP	3" LP
– Air	2" LP equipped with	2" LP equipped with	2" LP equipped with	2" LP equipped with
– Water	3" LP Weco union fig. 206	3" LP Weco union fig. 206	3" LP Weco union fig. 206	3" LP Weco union fig. 206
– Pilot gas	1/2" LP	1/2" LP	1/2" LP	1/2" LP
– Diesel oil				1/2" LP for upper head 2" LP for lower heads
Overall dimensions				
– Width	65" (1.65 m)	65" (1.65 m)	37.4" (0.95 m)	65" (1.65 m)
– Length	49" (1.25 m)	49" (1.25 m)	41.3" (1.05 m)	49" (1.25 m)
– Height	71" (1.80 m)	71" (1.80 m)	75" (1.90 m)	78" (1.98 m)
Weight	1660 lbs (750 kg)	1875 lbs (850 kg)	660 lbs (300 kg)	1800 lbs (810 kg)

POOR

QUALITY

ORIGINAL